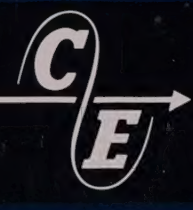
CE-40
FREQUENCY COUNTER

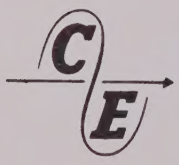


CUSHMAN
ELECTRONICS, INC.

CE-40

FREQUENCY COUNTER

PRELIMINARY



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5602-0020

CUSHMAN
ELECTRONICS, INC.

MANUAL CHANGE NOTICE

INSTRUMENT CE-40 MANUAL NO. 5602-0020 DATE PRINTED _____

The following changes are necessary to bring your manual up to date. Changes are listed with the instrument serial numbers to which they apply. It is suggested that you enter these changes in your manual immediately.

PAGE NO.	CHANGE
N/A	Serial No. 111 and Up.
(2400)	Schematic Circuit Ref 2400 - Delete Trace from S2-2 to input line X-20.

Date 8-14-72

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SCHEMATICS

CKT. REF.	
1000	Front Panel
2000	Mother Board
2100	Light-Emitting Diode
2200	Display
2300	Time Base
2400	Counter
3000	Rear Panel
3100	Regulator/Charger

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INTRODUCTION

This manual presents operating and maintenance information for the CE-40 Frequency Counter, which is used to measure frequencies in the 10 Hz to 999.9 kHz range. The CE-40, which operates on either ac current or on internal, rechargeable batteries, is primarily designed for use by both carrier craftsmen and station installers in the telephone industry. The instrument can be used by linemen who must maintain rural 'N' carrier repeater systems and remote repeaters. It can also be used for station installations when use of ac power is not convenient. The CE-40 may be used with the KS 'N' Line Deviation Test Set, which is a Bell System standard. A standard telephone input jack is used for the 310 plug. However, there are many other uses for such a versatile instrument in any field of electronics.

To facilitate reference to specific circuit detail and component descriptions in this manual, the text refers to each printed circuit board with a circuit reference series number, which is also marked on the pertinent schematic and parts list. Thus, those portions of the text relating to the time base board refer to board 2500, and the schematic and parts list relating to the time base board are also marked "2500".

SECTION 1

GENERAL INFORMATION

1.01 DESCRIPTION

The CE-40 is a portable, ac/battery-operated frequency counter used to measure and display frequencies from 10 Hz to 999.9 kHz. With four digits displayed, the count is varied by selecting the desired resolution (0.1 Hz, 1 Hz, 10 Hz, or 100 Hz) at the front-panel RESOLUTION switch.

The counted frequency is indicated by a LED (light-emitting diode) display capable of indicating four digits and a variable-position decimal point. The position of the decimal point varies with the resolution selected, and the resolution by which the frequency can be indicated depends on the frequency being counted. The kHz or Hz indicator illuminates as is appropriate according to the selected resolution. When the four digits of the display are not enough to display the number that represents the frequency, an OVERFLOW indicator lights.

When, for example, a frequency of 761, 234.5 Hz must be counted with maximum resolution, it is possible to start either with the best (0.1 Hz) or the minimum (100 Hz) resolution. If the example frequency is counted at the 0.1 Hz resolution, all 761, 234.5 cycles are counted, the display only shows 234.5 Hz, and the OVERFLOW light will be on. At a 1-Hz resolution, the display will show 1.234 kHz with the OVERFLOW light on. At a 10-Hz resolution, the display will show 61.23 kHz with the OVERFLOW light on. At the minimum resolution (100 Hz), the OVERFLOW light will go out and the display will show 761.2 kHz.

A self-test can be actuated by depressing the front-panel CHECK pushbutton. The test consists of counting an accurate signal of 1000 Hz derived from an internally-generated 2-MHz signal. Proper operation is indicated variously, depending on the resolution selected. A table of the various readouts is provided in section 3 of this manual.

The RESET button is primarily used when a 0.1 Hz or 1 Hz resolution is selected. At these resolutions, the counting times are quite perceptible, and resetting controls the beginning of a counting period.

Other features provided in the CE-40:

* When a frequency measurement is less than four digits, the system suppresses display of zeroes above the most significant digit that otherwise would be indicated.
* Fast, exact low-frequency measurements are obtained by means of halving the time normally required to obtain readings at the 0.1 Hz and 1 Hz resolutions after reset.
* A manual sensitivity control is unnecessary, and exact readings in the presence of noise are made possible by automatic gain control of the input amplifier.

The counter can be operated on either ac current or on internal, rechargeable batteries. Typically, the batteries permit 24 hours of operation. When battery recharging is required, the front panel RECHARGE indicator is lit.

The instrument is housed in a shock-resistant extruded aluminum case with a tilt-bale handle.

Specifications for the CE-40 are provided in table 1-1. Accessories supplied with the instrument are listed in table 1-2.

Table 1-1. Specifications

FREQUENCY	
Range	10.0 Hz to 999.9 kHz
Resolution	
.0 kHz to 999.9 kHz	100 Hz
.01 kHz to 99.99 kHz	10 Hz
.010 kHz to 9.999 kHz	1 Hz
10.0 Hz to 999.9 Hz	0.1 Hz
Accuracy	± 1 count ± time-base accuracy
Time-Base Accuracy	
Stability	± 10 ppm from 0°C to 50°C
Aging	± 5 ppm per year
DISPLAY	Four 7-segment numeric LED's 1/4" high Four Single LED's 1/8" diameter (RECHARGE, OVERFLOW, Hz, kHz indicators)
INPUT	
Connector	Receptacle to accept WE310
Level	
Operational	10 mV to 3V rms (Automatic Gain Control)
Maximum Protection (High Voltage)	660V peak for 3 ms, or 25V rms
Impedance	>10,000Ω
Minimum threshold between desired and undesired signal	≥15 dB
OPERATING TEMPERATURE	0°C to 50°C
POWER	
AC	115 or 230V ac, 50 to 400 Hz, 6.5 watts
Battery	Four 1.25, 4 AH rechargeable cells
Battery operating time	Typically more than 24 hours
DIMENSIONS (Less handle)	3-7/8" h x 6-3/4" w x 9-1/4" d
WEIGHT	7-1/4 pounds

Table 1-2. Supplied Accessories

Item	Description	Cushman Part No.	Quantity
1	Adapter, Cable Assembly (310 to BNC)	7030-0071	1
2	Bag, Plastic, 7" x 10"	5285-0005	1
3	Cord, Power (Detachable)	3170-0006	1
4	Manual, Operation and Maintenance (Preliminary)	5602-0020	1

SECTION 2

INSTALLATION

2.01 UNPACKING AND INSPECTION

When unpacking the CE-40 frequency counter, inspect the packing box and the instrument for signs of damage, and see if the accessories listed in table 1-2 are present. Verify satisfactory performance as outlined in the operating instructions (section 3) of this manual. If the instrument is damaged, fails to operate properly, or if any of the accessories is missing, file a claim with the transportation agency, or, if insured separately, with the insurance company.

2.02 INSTALLATION PROCEDURES

2.02.01 Power Requirements

The CE-40 operates from a 117-volt (±10%) ac source, 50-400 Hz; from a 230-volt (±10%) ac source, 50-400 Hz, when internal modifications have been made by the manufacturer; or on battery power alone. To prepare the instrument for battery-powered operation, turn the instrument off, remove the top cover, and connect the battery to its mating connector.

Power consumption is 0.7 va. A 1/8-amp slo-blo fuse in the CE-40 provides overcurrent protection. The battery is protected by a 1-amp fast-blo fuse.

2.02.02 Grounding Requirements

The CE-40 is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. To preserve this protection when operating the instrument from a two-wire outlet, use a three-prong to two-prong adapter and connect the green lead on the adapter to ground.

2.03 PREPARATION FOR RESHIPMENT

It is recommended that the shipping box and foam packaging be kept in case it becomes necessary to return the instrument to the factory for service or repair. If further assistance is required, contact Cushman Electronics, Customer Service Department.

The following paragraphs contain a general guide for repackaging of the instrument for shipment.

NOTE

If the instrument is to be shipped to Cushman Electronics for service or repair, attach a tag to the instrument identifying the owner, and indicating the service or repair to be accomplished. Include the model serial number. In correspondence, identify the instrument by model number and serial number.

If the original container is to be used, proceed as follows:

a. Place the instrument in the original container. (If the original container is not available, one can be purchased from Cushman Electronics.)

b. Ensure that the container is well sealed with strong tape or metal bands.

If the original container is not used, proceed as follows:

a. Wrap the instrument in plastic or heavy paper before placing in an inner container.

b. Place packing material around all sides of the instrument.

c. Place the instrument and inner container in a heavy carton or wood box, and seal with a strong tape or metal bands.

d. Mark the shipping container with "DELICATE ELECTRONIC INSTRUMENT," "FRAGILE."

2.04 SERVICE OR REPAIR

In the event service or repair of the instrument is required contact:

Cushman Electronics, Inc.

Customer Service Department

830 Stewart Drive

Sunnyvale, California 94086

Telephone: (408) 739-6760

or the southeastern service center:

BCS Associates, Inc.

940 North Fern Avenue

Orlando, Florida 32803

Telephone: (305) 843-1510

SECTION 3

OPERATING INSTRUCTIONS

3.01 CONTROLS AND INDICATORS

The location of front and rear-panel controls and indicators is illustrated in figure 3-1. These elements are listed and briefly described in table 3-1.

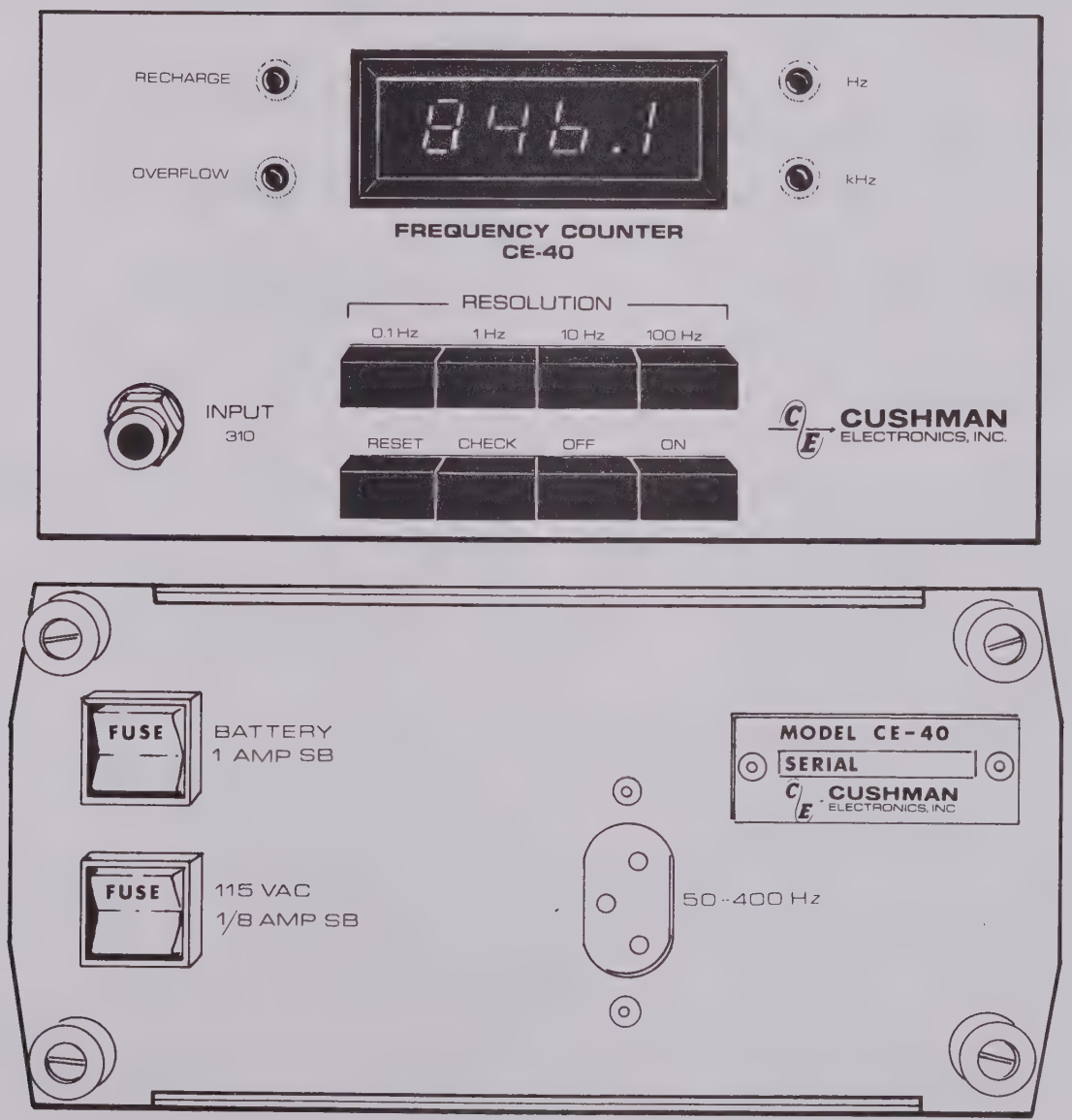


Figure 3-1. Front and Rear Panels

Table 3-1. Controls and Indicators

Name/Panel Description	Type	Reference Designation	Purpose
FRONT PANEL			
RESOLUTION	Four-pushbutton, mechanically-interlocked switch	S2301A/ S2301B/ S2301C/ S2301D	Used to select time base and corresponding range at which input frequency is counted.
RESET	Pushbutton switch	S2401	Used to set internal count and display to zero.
CHECK	Pushbutton switch	S2402	Used to initiate instrument self-testing.
OFF/ON	Two-pushbutton, mechanically-interlocked switch	S2403	Used to remove power from or to apply power to instrument.
INPUT 310	Telephone input jack	J1001	Connects input frequency to instrument.
RECHARGE	Light-emitting diode	CR2101	Lights when the battery voltage has reached a level below which reliable measurements cannot be made.
OVERFLOW	Light-emitting diode	CR2102	Lights when a frequency is being measured that exceeds the range of the selected resolution on the four-digit display.
Hz	Light-emitting diode	CR2103	Lights when a 0.1-Hz resolution is selected.
kHz	Light-emitting diode	CR2104	Lights when a 100-, 10-, or 1-Hz resolution is selected.
REAR PANEL			
117 VAC, GND, 50-400 Hz	Plug	P3001	Connector for cord to 115V ac power source.

c. To select the desired resolution and corresponding time base and frequency range, depress one of the following switch buttons:

Switch	Resolution	Frequency Counting Range
S2301D	100 Hz	.0 kHz to 999.9 kHz
S2301C	10 Hz	.01 kHz to 99.99 kHz
S2301B	1 Hz	.010 kHz to 9.999 kHz
S2301A	0.1 Hz	10.0 Hz to 999.9 Hz

3.03 RESET

To set the display and the internal count to zero, depress the RESET pushbutton (S1005). After it is reset, the counter is ready to begin a new counting cycle.

3.04 SELF-TESTING

To check the instrument's operation, depress the CHECK pushbutton (S1006). The reading that is displayed depends on the selected resolution, as indicated in table 3-2.

Table 3-2. Self-Testing Readings

Resolution	Reading
100 Hz	1.0
10 Hz	1.00
1 Hz	1.000
0.1 Hz	000.0 with overflow indicated

3.05 BATTERY RECHARGE

The battery may be recharged at any time. For recharging procedure, refer to step b-3, above.

3.06 TURN-OFF

Separate ON and OFF pushbutton switches are provided so that a plunger in the instrument cover depresses the OFF button whenever the cover is on the instrument.

SECTION 4

THEORY OF OPERATION

The following functional description of the CE-40 is keyed to the overall block diagram (drawing 3540000). The circuit description is keyed to the schematic diagrams of the instrument's six printed circuit boards: the mother board, the display board, the counter board, the LED board, the time-base board, and the regulator/charger board.

4.01 FUNCTIONAL DESCRIPTION

The CE-40 is used to measure frequencies in the 10-Hz to 999.9-kHz range. The count can be made with a resolution of 0.1 Hz, 1 Hz, 10 Hz, or 100 Hz, but only four digits are displayed at a time. The count accuracy is varied by selecting the desired resolution. Selecting the resolution causes variation of the counting time (time base), the longest counting time being required for the best resolution (0.1 Hz). The time base is derived from a 2-MHz crystal-controlled oscillator and depends on the selected resolution. The following correlation would be expected to exist between resolutions and counting times:

100 Hz	0.01 sec
10 Hz	0.1 sec
1 Hz	1 sec
0.1 Hz	10 sec

To shorten the longest counting times (1 and 10 seconds), two counts are made per cycle, and the counting time is halved. Thus, the correlation is as stated above for the 100 Hz and 10 Hz resolutions, but changes to:

1 Hz	0.5 sec, and
0.1 Hz	5 sec

for the smallest resolutions. These counting times or time bases are evident when comparing the waiting periods required to obtain an initial count at different resolutions. At the 0.1 Hz resolution, 5 seconds will elapse before an

indication is obtained; at 100 Hz resolution, the response seems immediate. At the 0.1-Hz resolution, the first count is produced after 5 seconds, but each subsequent "updating" count requires 10 seconds.

To count its frequency, a signal is applied to the front panel INPUT 310 jack, and a resolution switch button is depressed, determining the time base at which the input frequency is to be counted.

Referring to the overall block diagram, it can be seen that the main data flow is through circuits located on boards 2000, 2200, 2400, and 2100.

The input signal is amplified and shaped into a rectangular wave, and is fed to the times-two multiplier, which is associated with halving the time base at the 1-Hz and 0.1-Hz resolutions. The signal is then fed through the main gate, which remains open for a length of time determined by the selected time base. The cycles passed through the main gate are counted. After all the counters have finished counting, the data is deposited in the storage registers associated with the counters. The data is transferred by the strobe gates from storage to the display driver, which decodes the BCD information and feeds it to the LED board for display. When, at a selected resolution, the four digits of the display are not enough to display the number that represents the frequency, an OVERFLOW indicator lights. After the frequency is counted and stored, the counters are automatically reset and begin a new count.

System operation is controlled with signals derived from a 2-MHz crystal-controlled oscillator on the time base board (2300). The 2-MHz sinewave output of this oscillator is shaped and divided down to a 1-MHz signal that is used to provide the four time bases; to synchronize the time base and counters; to provide the triggering impulses for the strobe gates, display driver, and numeric LED's; and to provide the 1-kHz self-test signal.

4.01.01 Time Bases

The 1-MHz signal consists of positive and negative alternations that are each 500 nanosec in duration, a full cycle having a duration of 1 microsec. A time-base signal is formed by dividing the signal frequency by 10^4, 10^5, 5×10^5, and 5×10^6, which produces signals with frequencies of 100 Hz, 10 Hz, 2 Hz, and 0.2 Hz. In a signal with a frequency of 100 Hz, a cycle lasts 1/100 sec, which

means that the time lapse between trailing edges of the positive alternations of the cycle is 1/100 sec. For the other frequencies this time is 1/10 sec, 1/2 sec, and 5 sec.

When a to-be-counted signal frequency is applied to the main gate, a frequency with a cycle duration corresponding to that of the selected time base (the count inhibit signal) is also applied to the main gate. The main gate is opened when the dc levels of these two inputs are both high.

The time lapse between the leading and trailing edges of the positive alternations of the count inhibit signal cycles is actually twice as long as is the case for the time base signal cycles that are represented by the count inhibit signal frequency. Since, during a cycle, the dc level is high for only half of the duration of the cycle, doubling the time lapse (in effect, doubling the pulsewidth) provides a high dc level with a duration directly representative of the duration of a full time base cycle.

The time the gate is open, then, is varied according to the resolution selected. Since there are only four numeric LED's, the selected resolution affects the frequency value that can be displayed without OVERFLOW.

Time Base	Frequency Counting Range	Resolution	Display Update Time
0.01 sec	.0 kHz through 999.9 kHz	100 Hz	0.1 sec
0.1 sec	.01 kHz through 99.99 kHz	10 Hz	0.2 sec
0.5 sec	.010 kHz through 9.999 kHz	1 Hz	1.0 sec
5.0 sec	10.0 Hz through 999.9 Hz	0.1 Hz	5.0/10.0 sec*

* 5 seconds for first reading after reset; 10 seconds for remainder of readings

The correlation between what is actually counted due to resolution and corresponding counting time and the frequency of which this count is representative (to-be-counted frequency) is made by placement of the decimal point and lighting the appropriate units indicator (kHz or Hz).

If the to-be-counted frequency had been 100 Hz and this was counted at a 100-Hz resolution, the number of cycles passed through the gate would have been 1 in 1/100 sec. The display would have shown ---.1 kHz, where the dashes

indicate that these "insignificant" digits are not being displayed.

4.01.02 Time Base Synchronization

After a time base is selected, the time base pulse is not sent directly to the main gate but is sent to the synchronizer on board 2300. In the synchronizer, a 1-MHz signal derived from the 2-MHz oscillator is used to clock the selected time base pulse so that energizing of the storage registers, resetting of the counters, and transfer of data from the storage registers to the strobe gates occur at synchronous intervals after closure of the main gate.

4.01.03 Strobe Gate and LED Drives

A 100-Hz signal derived from the 2-MHz oscillator is used to produce signals that energize the strobe gates and LED's. Four lines, each with a 100-Hz prf, are received by the decoder on the time base board. These lines are energized sequentially, no two being energized simultaneously. The 100-Hz signals are decoded to produce signals that energize lines to the strobe gates and LED's. Each of the four lines simultaneously energizes a strobe gate and the LED associated with that gate. Since no two lines are on at any one time, the strobe gates are separately enabled to transfer data from storage, and the LED's are accordingly separately energized, causing a strobed display. Although the display is strobed, the operator sees a stable visual display because the strobing occurs at a speed greater than the eye can distinguish.

4.01.04 Display Driver Drive

The signals on the four 100-Hz lines are also used to energize the display driver drive. The multiplexer also receives DECE register signals, indicating that the decade counters are energized. When a counter is energized, a signal from the DECE register associated with that counter is multiplexed with one of the decoded 100-Hz signals, resulting in an enabling signal that is fed to the circuits that drive the display driver.

Inhibiting the energizing line to the display driver drive suppresses display of nonsignificant zeroes (ZERO SUPPRESS). When a counter has not been counting, the zero count is still deposited in the storage register associated with that counter, and the strobe gates are still enabled to transfer the stored data -- whether or not the data is a nonsignificant zero. Because the counter has not

been counting, the logic does not receive a DECE signal; therefore, the display driver is not energized and cannot receive the nonsignificant zero from storage.

Figure 4-1 illustrates the sequence of events for signal flow from a decade counter to display, and the zero suppress function.

4.01.05 System Self-Testing Signal

A 1-kHz signal derived from the 2-MHz oscillator output is used to check system operation. The 1-kHz signal enters the input amplifier and travels along the main signal path to the display.

4.02 DETAILED CIRCUIT ANALYSIS

The CE-40 has six printed circuit boards -- the mother board (2000), the display board (2200), the counter board (2400), the LED board (2100), the time base board (2300), and the regulator/charger board (3100).

The mother board carries circuits used in the initial processing of the main signal and circuits used to initiate system self-testing. The mother board also provides system interconnections. The display board plugs into the mother board at J2001; the counter board plugs into the mother board at J2003; and the time base board plugs into the mother board at J2002.

The display board is used to process the main signal in three phases of the signal path: (1) a phase in which the to-be-counted signal is processed prior to being counted; (2) a phase in which part of the signal is actually counted; and (3) a phase in which the already-counted signal is decoded and transmitted to the LED board for display. The display board also carries elements of some drive circuits and of some of the reset circuitry. An interconnection is provided by the display board for the LED board, which plugs into the display board at J2201.

The counter board is used primarily for counting the main frequency. This board also carries part of the system reset circuitry.

Circuits on the time base board provide signals used to control the timing of system operation and used to provide drives for circuits on the display and counter boards. The time base board also carries part of the system reset circuitry and provides a signal used in system self-testing.

The LED board is used to carry circuits providing various elements of the front panel display.

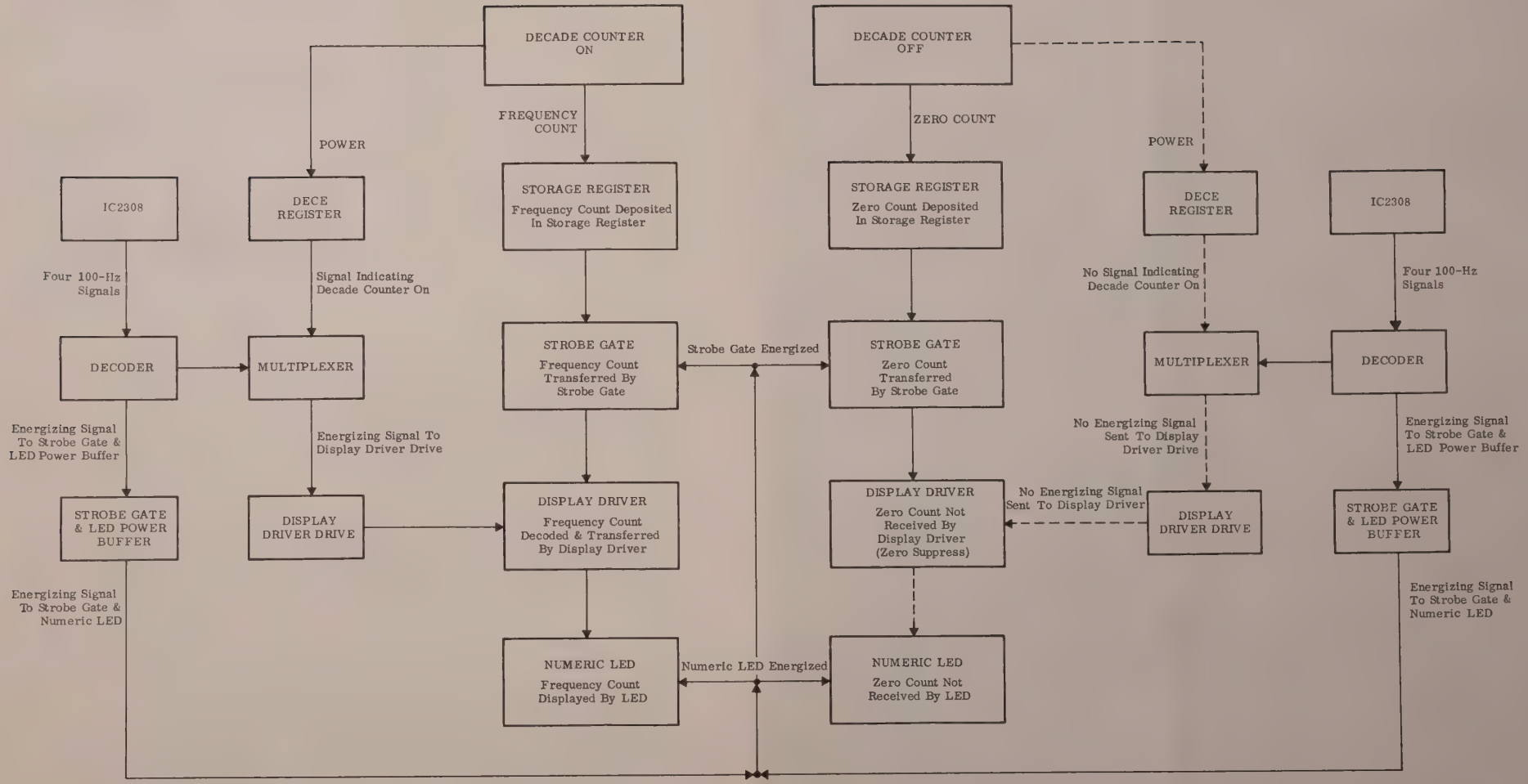

DECADE COUNTER ON
DECADE COUNTER OFF
POWER
FREQUENCY COUNT
ZERO COUNT
POWER
IC2308
DECE REGISTER
STORAGE REGISTER
Frequency Count Deposited In Storage Register
STORAGE REGISTER
Zero Count Deposited In Storage Register
DECE REGISTER
IC2308
Four 100-Hz Signals
Signal Indicating Decade Counter On
No Signal Indicating Decade Counter On
Four 100-Hz Signals
DECODER
MULTIPLEXER
STROBE GATE
Frequency Count Transferred By Strobe Gate
Strobe Gate Energized
STROBE GATE
Zero Count Transferred By Strobe Gate
MULTIPLEXER
DECODER
Energizing Signal To Strobe Gate & LED Power Buffer
Energizing Signal To Display Driver Drive
No Energizing Signal Sent To Display Driver Drive
Energizing Signal To Strobe Gate & LED Power Buffer
STROBE GATE & LED POWER BUFFER
DISPLAY DRIVER DRIVE
DISPLAY DRIVER
Frequency Count Decoded & Transferred By Display Driver
DISPLAY DRIVER
Zero Count Not Received By Display Driver (Zero Suppress)
No Energizing Signal Sent To Display Driver
DISPLAY DRIVER DRIVE
STROBE GATE & LED POWER BUFFER
Energizing Signal To Strobe Gate & Numeric LED
Energizing Signal To Strobe Gate & Numeric LED
NUMERIC LED
Frequency Count Displayed By LED
Numeric LED Energized
NUMERIC LED
Zero Count Not Received By LED

Figure 4-1. Signal Flow From Decade Counter to Display, and Zero Suppress Function: Sequence of Events

The regulator/charger board provides a power supply for system operation.

Because the path of the to-be-counted signal and of auxiliary system functions (such as reset and self-testing) overlap among the various boards, the circuits are described by function rather than on a board-by-board basis. The following circuit analysis describes first the circuit elements used in the system counting function, together with the drive signals associated with these elements; then, the circuit elements used in the generation of signals providing control of the timing system operation and drives for various system elements; and, finally, the circuit elements used in the reset and self-testing functions. The power supply is also described.

4.02.01 System Counting Circuits

4.02.01.01 Input Amplifier

The input signal is applied to jack J1001 and is fed to the mother board (2000) via WT2001. The signal is passed through R2001, C1001 and CR1001 and CR1002, which limit the input voltage to 0.4v p-p. The signal is then fed via Q2001 to the input amplifier, which consists of Q2002, Q2003, and associated components. A feedback circuit (C2010, R2009, CR2005 and CR2006) provides gain control.

4.02.01.02 Waveshaper

The signal is shaped into a rectangular wave by the Schmitt trigger (Q2004 on board 2000 and inverter IC2203-8, 9, 10 on board 2200). The signal ($\overline{\text{AMP OUT}}$) is fed from board 2000 to IC2203-8, 9, 10 on board 2200 via P2201-4. The rectangular wave produced at the output (pin 8) of IC2203 is fed to the times-two multiplier.

4.02.01.03 Times-Two Multiplier

The times-two multiplier (X2), located on board 2200, is used to produce two pulses for each cycle of the to-be-counted signal at the 1-Hz and 0.1-Hz resolutions at the same time that the time base is halved. To provide the equivalent of a full frequency count at these halved time bases, two pulses are counted for each cycle of the main signal.

The X2 consists of IC2201; IC2203-pins 1 through 6; and IC2203-pins 11, 12, 13; diodes CR2202 and CR2203; and associated components. When switch S2301A or S2301B is depressed, an enabling signal (X2) from terminal 2 of either switch is fed via P2301-8/J and P2201-8 to the X2. When the X2 is enabled, its output is a pulse for every transition of the input signal waveform (2 per cycle). The resulting "twin pulse" signal is gated by IC2203-pins 1, 2, 3 to the main gate. When the X2 is not enabled, its output is one pulse for every cycle.

4.02.01.04 Main Gate

The main gate, also located on board 2200, is used to pass pulses representing cycles of the to-be-counted signal. The main gate (IC2204-pins 11, 12, 13) is triggered by the count inhibit (CNT INH) signal, and pulses are passed through the main gate as long as the dc levels of the to-be-counted pulses and of the count inhibit signal are both high. The count inhibit signal, which is produced by the synchronizer on board 2300, enters board 2200 via P2201-D. The groups of pulses passed by the main gate leave board 2200 via P2201-R and pass to the decade counters on board 2400.

4.02.01.05 Decade Counters

Decades on the counter board (2400) and the display board (2200) are used to count the number of pulses in each group of pulses passed by the main gate. The counters are IC2401, IC2409, and IC2412 on board 2400, and IC2206 on board 2200.

IC2401 produces one pulse for every 10 input pulses. At count 8, a pulse triggers latch IC2405-pins 1 through 6, which enables the second decade counter, IC2409. At count 10 of IC2401, one output pulse is produced, which is counted by IC2409. The second, third, and fourth decade counters are identical to IC2401, and function similarly. The 8-count from IC2409 triggers latch IC2410-pins 1 through 6, which enables IC2412. The 8-count from IC2412 triggers the latch on board 2200, IC2207-pins 8 through 13, which enables IC2206.

A correlation with the numeric display can be made by calling IC2401 the least significant digit (LSD) decade; IC2409, the third most significant digit (3rd MSD) decade; IC2412, the second most significant (2nd MSD) decade; and IC2206, the most significant digit (MSD) decade.

The four decade counters continue counting for as long as there are pulses

left to be counted in the group of pulses passed by the main gate. There is, however, no decade counter that counts the output pulses of the MSD decade, so that the number of times the MSD decade reaches a 10-count is not registered. When more pulses than can be registered are passed through the main gate, there is an overflow. The output pulses of the MSD decade, although they are not counted, are used to light the OVERFLOW light by triggering the OVERFLOW-LED driver (Q2212 and associated components).

When the four decade counters have counted all the pulses the main gate let through during one time-base unit, the total count is deposited in the storage registers.

The latching signal produced by the 2nd MSD decade, designated $\overline{\text{RESET D4}}$, leaves board 2400 via P2401-16/T, and is fed to the MSD decade on board 2200 via P2201-16. The output pulse from the 2nd MSD decade, designated INPUT D4, leaves board 2400 via P2401-19/W and is fed to the MSD decade on board 2200 via P2201-20/X. The OVERFLOW DRIVER output leaves board 2200 at J2201-A.

4.02.01.06 Storage Registers

The storage registers store the finished count for display while the decade counters are being cleared for a new count. A storage register is associated with each decade counter. The storage register consisting of IC2402 and IC2403 is associated with the LSD decade, and is called the LSD storage register. The storage register consisting of IC2407 and IC2408 is associated with the 3rd MSD decade and is called the 3rd MSD storage register. The storage register consisting of IC2416 and IC2417 is associated with the 2nd MSD decade and is referred to as the 2nd MSD storage register. The storage register consisting of IC2209 and IC2210, located on board 2200, is associated with the MSD decade also on board 2200, and is called the MSD storage register.

The finished count is deposited in the storage registers and is transferred from the registers when they are triggered by the memory clock signal ($\overline{\text{MEM CLK}}$) from the synchronizer on board 2300. The $\overline{\text{MEM CLK}}$ signal enters board 2400 via P2401-21, and is gated to the LSD and 3rd MSD storage registers by IC2415-pins 1, 2, 3, and to the 2nd MSD storage register by IC2415-pins 11, 12, 13. The $\overline{\text{MEM CLK}}$ is also fed to board 2200, at P2201-15/S, and is gated to the MSD storage register by IC2204-pins 4, 5, 6.

The 3rd MSD, 2nd MSD and MSD storage registers are energized by the flip-flop power signal, which is activated by latch IC2204-pins 1, 2, 3, and IC2204-pins 8, 9, 10, and flip-flop IC2205-pins 9, 11, 12, on board 2200. Part of the main frequency passed through the main gate is gated by IC2204-pins 1, 2, 3 and IC2204-pins 8, 9, 10 to flip-flop IC2205-pins 9, 11, 12. IC2205-pins 9, 11, 12 is triggered by the $\overline{\text{CNT INH}}$ signal, which is produced by the synchronizer on board 2300, and enters board 2200 at P2201-7/H.

The output at pin 9 of IC2205 is buffered by the flip-flop power buffer, consisting of Q2209 and associated components. The drive signal is then fed to the MSD storage register flip-flops on board 2200, and, via P2201-21/Y and P2401-20/X, to the 3rd MSD and 2nd MSD storage registers on board 2400. Since the LSD storage register is always energized, it is not connected to the flip-flop power signal.

4.02.01.07 Strobe Gates

The strobe gates transfer information from the storage registers to common busses that carry the data to the display driver. As noted above, this transfer occurs when the memory clock signal is received by the storage registers.

A strobe gate is associated with each decade counter. On board 2400, strobe gate IC2404 is associated with the LSD decade and is called the LSD strobe gate; strobe gate IC2411 is associated with the 3rd MSD decade and is referred to as the 3rd MSD strobe gate; and strobe gate IC2414 is associated with the 2nd MSD decade and is called the 2nd MSD strobe gate. On board 2200, strobe gate IC2208 is associated with the MSD decade and is referred to as the MSD strobe gate.

The first section (IC2404-pins 1, 2, 3) of the LSD strobe gate transfers the data via a buss connected to the first section of the 3rd MSD strobe gate and the 2nd MSD strobe gate (IC2411-pins 8, 9, 10 and IC2414-pins 8, 9, 10). This buss (D1) leaves board 2400 via P2401-7/H and enters board 2200 via P2201-L, where it receives the information from the first section of the MSD strobe gate (IC2208-pins 1, 2, 3). Similarly, the second-, third-, and fourth-section outputs from the three strobe gates on board 2400 are transferred on common busses (via P2401-5/E, P2401-6/F, and P2401-8/J) to board 2200, where the second-,

third-, and fourth-section outputs from the MSD strobe gate are added to the appropriate busses.

The strobe gates are powered by signals produced by the multiplexer on board 2300 and buffered by circuits on board 2200. The energizing signals for the LSD, 3rd MSD, 2nd MSD, and MSD strobe gates, $\overline{\text{DISP/STB 4 DR}}$, $\overline{\text{DISP/STB 3 DR}}$, $\overline{\text{DISP/STB 2 DR}}$, and $\overline{\text{DISP/STB 1 DR}}$, leave board 2300 via P2301-13/P, 12/N, 11/M, and 9/K, and enter board 2200 via P2201-13/P, N, 11/M, and 12. These signals are fed to the strobe gate and LED power buffer (Q2203, Q2205, Q2206, Q2207, and associated components).

After buffering, the $\overline{\text{DISP/STB 4 DR}}$ signal is fed simultaneously to the LSD strobe gate and to the LSD LED (i.e., LED 4). This signal is fed to the anode of the LSD LED via J2201-8/J and, with the schematic designation of DISP 4 STB, is fed via P2201-10 to the LSD strobe gate on board 2400 via P2401-10/L.

The buffered $\overline{\text{DISP/STB 3 DR}}$ signal is fed simultaneously to the 3rd MSD strobe gate and to the 3rd MSD LED (i.e., LED 3). This signal is fed to the anode of the 3rd MSD LED via J2201-6/F and, with the schematic designation of DISP 3 STB, is fed via P2201-14 to the 3rd MSD strobe gate on board 2400 via P2401-14/R.

The buffered $\overline{\text{DISP/STB 2 DR}}$ signal is fed simultaneously to the 2nd MSD strobe gate and to the 2nd MSD LED (i.e., LED 2). This signal is fed to the anode of the 2nd MSD LED via J2201-2, and, schematically designated DISP 2 STB, is fed via P2201-17 to the 2nd MSD strobe gate on board 2400 via P2401-17/U.

The buffered $\overline{\text{DISP/STB 1 DR}}$ signal is fed simultaneously to the MSD strobe gate and to the MSD LED (i.e., LED 1). The signal is fed to the anode of the MSD LED via J2201-1 and to the MSD strobe gate on board 2200.

4.02.01.08 DECE Registers

When the 3rd MSD, 2nd MSD, and MSD decades are energized to perform a count, information that this energized status exists is stored in the DECE registers associated with the decade counters. On board 2400, the DECE registers are IC2406 (3rd MSD DECE register), associated with the 3rd MSD decade, and IC2418 (2nd MSD DECE register), associated with the 2nd MSD decade. On board

2200, DECE register IC2211 (MSD DECE register) is associated with the MSD decade. The DECE register signals are fed to board 2300 where they are used by the multiplexer to produce signals to energize the display driver. Signals from the 3rd MSD and 2nd MSD DECE registers ($\overline{\text{DEC 2E}}$ and $\overline{\text{DEC 3E}}$) are transmitted from board 2400 via P2401-11/M and P2401-18/V to board 2300; the signal from the MSD DECE register ($\overline{\text{DEC 4E}}$) is transmitted from board 2200 via P2201-Z to board 2300.

The LSD decade is always energized because there is no preceding decade counter to energize it at its 8-count; therefore, it requires no associated DECE register.

4.02.01.09 Display Driver

Each numeric LED consists of an array of light-emitting diodes arranged to form seven bar segments. When appropriate segments are energized, all numbers from 0 through 9 can be made to appear.

The display driver (IC2212 and associated components) is a decoder that converts the BCD information from the storage registers into information that can be used to light only those segments that are required to form the appropriate digit in the display. The BCD information enters the board at P2201-E, J, K, and L. The decoded signals are fed to the LED board (2100) via J2201-9/K, 10/L, 11/M, 12/N, 13, 14, and 15.

The display driver is energized by the DD DRIVE signal from the multiplexer on board 2300. This power signal enters board 2200 via P2201-19/W and goes to the display driver drive power buffer (Q2208 and associated components). The buffered drive signal enters the display driver via terminals 3, 4, 5, and 16.

4.02.01.10 Light-Emitting Diodes

The numeric LED's that display the frequency count display the MSD, LED 1; the 2nd MSD, LED 2; the 3rd MSD, LED 3; and the LSD, LED 4.

Each of the seven segments in a numeric LED is connected to the segments in the other numeric LED's that occupy the same relative position on the LED. That is, there are seven busses to which are connected all segments of all numeric LED's according to physical position within the LED. This can be

done because although the human eye cannot see it, no two numeric LED's are actually on at the same time.

The chips that contain the seven segmented numeric LED's also contain separate LED's that form the decimal points. This is the case with all but LED 1, representing the MSD.

In all four LED packages (chips), all segments and decimal points are connected to a common operating voltage supply point (all anodes are connected to the VCC terminal on the chip). The operating voltage supply points, however, receive a voltage only when the digit is of significance (other than zero) and when it is the turn of that digit to be lit.

In order that a segment or a decimal point may light, the LED's in that segment should be between VCC and ground. Thus, ground returns are provided when it is necessary to light a particular segment or decimal point. To be off, a segment must be between VCC and an open circuit.

The BCD information is decoded in the display driver to seven-segment information, which means that at any given moment only those segments of an LED are lit that are required to form the number that corresponds to the binary code representing the count made by the associated decade counter.

The numeric LED's are not provided with VCC at the same instant. Each numeric LED is powered (strobed) in the same sequence as its associated strobe gate, storage register, and decade counter. All these elements are powered sequentially, and at any given instant, the display driver only decodes the information derived from one decade counter, while at that same instant, the appropriate segments in the proper numeric LED are provided with a ground return and VCC voltage.

The display driver outputs enter the LED board via P2101-13, 12/N, 11/M, 10/L, 9/K, 15, and 14. Each of these inputs connects to one of the seven busses.

The LED drives (VCC) from the strobe gate and LED power buffer enter board 2100 via P2101-8/J, 6/F, 2, and 1, and go to the anodes of, respectively, LED 4, LED 3, LED 2, and LED 1.

4.02.01.11 Decimal Point Display

The LED's which form the decimal points are sequentially powered when the rest of the LED package (numeric LED's) is powered. The other sides of these LED's (cathodes) are, however, connected to ground or open circuits, depending on which of the RESOLUTION pushbuttons is depressed. When S2301C (10 Hz) is depressed, the cathode of the decimal point B (DPB) LED is connected to ground. The LED will only light when its anode is (sequentially) powered, but to the eye, it appears to light steadily. This LED (DPB) is open-circuited when S2301C is not depressed and therefore off.

When S2301B (1 Hz) is depressed, the cathode of the decimal point C (DPC) LED is connected to ground. This LED is turned off because its cathode is disconnected when not depressed. Decimal point A (DPA) is on when either S2301A (0.1 Hz) or S2301D (100 Hz) is depressed, but neither S2301A nor S2301D directly controls its grounding. In actuality, DPA lights not because either S2301A or S2301D is depressed, but because S2301B or S2301C is <u>not</u> depressed. This is because when either the B or C button of S2301 is depressed, VCC is removed from one of the inputs of IC2316-pins 4, 5, 6. When both these inputs are high, the output of IC2316-pins 4, 5, 6 is low, and the output of IC2319-pins 8, 9 is high. When the latter output is high, Q2210 conducts and provides a ground for DPA. When one of the inputs to IC2316-pins 4, 5, 6 is not at VCC level, Q2210 does not conduct and DPA is open-circuited.

The DPA signal is fed via P2301-18 and P2201-18/V to board 2200, travelling to the DPA buffer/inverter (Q2210 and R2234). The signal is fed via J2201-3 to board 2100. The signal for DPB is fed via P2301-6/F and P2201-6/F to board 2200, passes through R2201, and is fed via J2201-7/H to board 2100. The DPC signal is fed via P2301-17/U and P2201-U to board 2200, passes through R2204, and is fed via J2201-5/E to board 2100.

4.02.01.12 Measurement Unit, Overflow, and Recharge Displays

The two measurement unit indicators (Hz, kHz) CR2103 and CR2104 are both controlled by the same signal (HZ DISP). The Hz DISP signal is VCC voltage which is applied to the base of Q2202. This transistor conducts and provides a path to ground for CR2103 (Hz). The VCC voltage is permanently supplied to the anode of this LED, but it lights only when Q2202 receives VCC at its

base resistor. When VCC is removed from the base of Q2202, Q2202 continues to conduct, but not enough to pass the amount of current required to light CR2103. The amount it does pass is enough, however, to provide Q2204 with the bias it requires to provide a path to ground for CR2104 (kHz).

The ground path for CR2102 (OVERFLOW) is provided by Q2212, which receives a bias voltage when IC2202 receives a signal that the MSD decade has made a ten-count.

The recharge indicator drive (Q2201, R2205, R2206, R2207, and zener diode CR2201) provides current to light the RECHARGE LED display when the battery voltage level is insufficient to operate the instrument reliably. The RECHARGE LED is normally tied to the VCC signal that is fed from the display board via J2201-C to the LED board, travels through LED CR2101, and reenters the display board via J2201-B. Current passes through Q2201, and goes to R2205, R2206, and CR2201 to ground, dissipating the current. When, however, the VCC voltage at the junction between Q2201 and R2205 drops, Q2201 goes high, and current passes to the RECHARGE indicator through J2201-B.

4.02.02 System Control Signals

Signals used to control system operation are derived from the output of the 2-MHz crystal-controlled oscillator on board 2300, the time base board. The 2-MHz sinewave generated by this oscillator is shaped into a rectangular wave that is processed by other circuits on board 2300 to provide the system control signals, as follows:

* Decade Dividers, which are used to provide time base signals; signals used to produce drives for the strobe gates, display driver, and numeric LED's; and 1-kHz self-test signal.
* Synchronizer, which is used to provide timing signals that control gate time of the main gate; activate the flip-flop power drive; control transfer of data from the storage registers; and control automatic reset operation.
* Resolution Switch, which is used to select the appropriate time base; to enable the times-two multiplier, where appropriate; to provide for correct decimal point placement and measurement.

* Decoder/Multiplexer, which is used to produce drives for the strobe gates, display driver, numeric and decimal-point LED's.

4.02.02.01 2-MHz Crystal-Controlled Oscillator

The 2-MHz crystal-controlled oscillator (crystal Y2301, transistor Q2301, and associated components) generates a 2-MHz sinewave that is converted to a rectangular wave by waveshaper Q2302 and associated components. The shaped wave is divided by two by IC2302-pins 5, 6, 7, 9, 10, and the resulting 1-MHz signal is fed to the decade dividers to be divided down to frequencies used for time base signals, drive signals, and the 1-kHz self-test signal. The synchronizer also receives part of the 1-MHz signal, which is used to clock the time base pulses before they are transmitted to the main gate, decade counters, storage registers, and flip-flop power drive.

4.02.02.02 Decade Dividers

The decade dividers process the 1-MHz signal derived from the crystal-controlled oscillator down to various frequencies used for the four time bases, for drive signals, and for the self-test signal.

Time Base Signals

As described earlier, each time base is a unit of time represented by a period between trailing edges of two pulses. A frequency with a cycle duration corresponding to that of the selected time base and the to-be-counted signal frequency are both applied to the main gate, which is opened when the dc levels of these two inputs are both high.

For each time base, a 1-MHz signal frequency is divided by different amounts to produce pulses the trailing edges of which occur at fixed intervals. The fourth through seventh dividers provide the four signals used as time base signals.

The 1-MHz signal is divided by decades IC2301, IC2304, IC2306, and IC2308, resulting in a 100-Hz frequency that is associated with a pulse repetition frequency of 0.01 second. The 0.01-second prf is the time base associated with the 100-Hz resolution and permits a display of frequency values over a range of from 100 Hz through 999.9 kHz.

The 100-Hz frequency is divided by decade IC2310 to 10 Hz, which corresponds to a 0.1-second prf that is used as the time base associated with the 10-Hz resolution, permitting frequency values from 10 Hz to 99.99 kHz to be displayed.

The 10-Hz frequency is divided by five by divider IC2312, resulting in a 2-Hz frequency and an associated prf of 0.5 seconds. At a 1-Hz resolution, signal cycles are counted over an 0.5-second time base rather than the 1-second time base normally expected at a 1-Hz resolution. When the time base is halved, the times-two multiplier is used to provide two pulses for each cycle of the input frequency, resulting in an accurate frequency count in half the time otherwise required. The range that can be displayed at this resolution is from 1 Hz to 9.999 kHz.

The 5-Hz frequency is divided by decade IC2315, resulting in a 0.2-Hz frequency and associated 5-second prf. At the 0.1-Hz resolution signal cycles are also counted over a halved time base. The 10 seconds that would otherwise be required to count cycles at a 0.1-Hz resolution has been halved to 5 seconds, and the times-two multiplier is used to produce two pulses for each input frequency cycle, thus providing a faster frequency count.

Each of the four dividers is connected to a section of the resolution switch through which the time base signal is transmitted to the synchronizer. Table 4-1 shows the correlation between the resolution switch sections and the decade dividers, the divider output frequencies, and the corresponding time bases. In all cases, the connections are made to terminal 4 of a switch. Also shown are the resolution and frequency counting range associated with each switch.

Table 4-1. Correlation Among Resolution Switch Sections, Decade Dividers and Time Bases

Switch	Resolution	Frequency Counting Range	Divider	Divider Output Frequency	Time Base	Update Time
S2301D	100 Hz	.0 kHz - 999.9 kHz	IC2308, pin 12	100 Hz	0.01 sec	0.1 sec
S2301C	10 Hz	.01 kHz - 99.99 kHz	IC2310, pin 12	10 Hz	0.1 sec	0.2 sec
S2301B	1 Hz	.010 kHz - 9.999 kHz	IC2312, pin 10	2 Hz	0.5 sec	1.0 sec
S2301A	0.1 Hz	10.0 Hz - 999.9 Hz	IC2315, pin 12	0.2 Hz	5.0 sec	5 sec/10 sec*

* 5 seconds for first reading after reset;
10 seconds for remainder of readings.

Drive Signals

The 100-Hz output of divider IC2308 is used to energize four lines between the divider and the decoder. The signals on these four lines are used by the decoder and by the multiplexer to provide drives for the strobe gates, LED's, display driver, and decimal point and measurement unit displays.

Self-Test Signal

A 1-kHz frequency produced at the output of divider IC2306 is used as the system self-test signal. The 1-kHz signal is gated through IC2319 and travels via P2301-14/R to the mother board.

4.02.02.03 Synchronizer

The synchronizer is used to synchronize the pulses of the time base signal with those of the 1-MHz clock signal derived from the 2-MHz oscillator output. The time base signals are transmitted to the synchronizer via the resolution switch. The synchronizer output consists of four signals: the count inhibit signal, which consists of the pulses that are used to open and close the main gate according to time base selection; the negative complement of the count inhibit signal, which consists of pulses that activate the flip-flop power drive circuits; the memory clock signal, which consists of pulses that enable the storage registers to deposit the stored data in the strobe gates for transfer to the display driver; and the automatic reset signal, which consists of pulses that reset the decade counters and latches associated with those counters.

The synchronizer consists of IC2302-pins 1, 2, 3, 12, 13, 14, IC2305, and associated components. The time base signal selected at the resolution switch comes via pin 1 into IC2302, which is used to double the pulsewidth. The pulse levels then are of durations directly representative of the durations of full time base cycles. The doubled pulsewidth is the count inhibit signal, which leaves the board via P2301-4/D (CNT INH), and is fed via P2201-D to the main gate on board 2200.

The complement to the count inhibit signal is the negative, or "not" count inhibit signal, designated $\overline{\text{CNT INH}}$ on the schematics. This signal is fed via P2301-7/H and P2201-7/H to board 2200 where the signal is used to activate the flip-flop power drive.

The stretched pulse also goes to IC2305-pins 1, 2, 3, 12, 13, 14. Up to a maximum of 1 μsec after the time base pulse has been received by IC2302-pins 1, 2, 3, 12, 13, 14, the time base pulse is triggered by that integrated circuit on the first trailing edge of the incoming 1-MHz clock signal. This synchronizes the time base signal and the 1-MHz clock signal so that the edges of each signal occur at the same time.

The signal then is fed to IC2305-pins 5, 6, 7, 9, 10. Between 1 and 2 μsec after the time base pulse has been received by IC2302-pins 1, 2, 3, 12, 13, 14, IC2305-pins 5, 6, 7, 9, 10 is triggered on the first trailing edge of the 1-MHz clock. The outgoing signal is differentiated by C2302 and R2308. The differentiated signal is inverted by IC2317-pins 1, 2, 4, 5, 6, and leaves the board via P2301-15/S as the memory clock signal ($\overline{\text{MEM CLK}}$), travelling via P2401-21 and P2201-15/S to boards 2400 and 2200 to be gated to the storage registers. The signal is inverted by IC2307-pins 11, 12, 13, and is gated by IC2307-pins 8, 9, 10 and IC2319-pins 1, 2. This signal is the automatic reset signal ($\overline{\text{AUTO RESET}}$), which is fed via P2301-16/T, P2401-15/S, and P2201-T to the decade counters and associated latches on boards 2400 and 2200.

Figure 4-2 provides a timing diagram for the synchronizer.

4.02.02.04 Resolution Switch

The resolution switch is a four-section pushbutton switch mounted at the front panel and connected to board 2300. Each section of the switch controls selection of a frequency resolution and corresponding counting range and time base. The switch also is used as a link between the time base signals and the synchronizer. Various switch sections are also used in association with the times-two multiplier; decimal point placement on the front panel display; and the appropriate measurement unit display. A description of the switch operation in relation to each of these functions is provided in the circuit analysis of each function.

4.02.02.05 Decoder/Multiplexer

The decoder and the multiplexer are used to provide signals on four lines to energize the strobe gates and the LED's, and one signal carried on another line to energize the display driver. The multiplexer also is used to enable or disable a line to decimal point A. Inputs to the decoder and the multiplexer

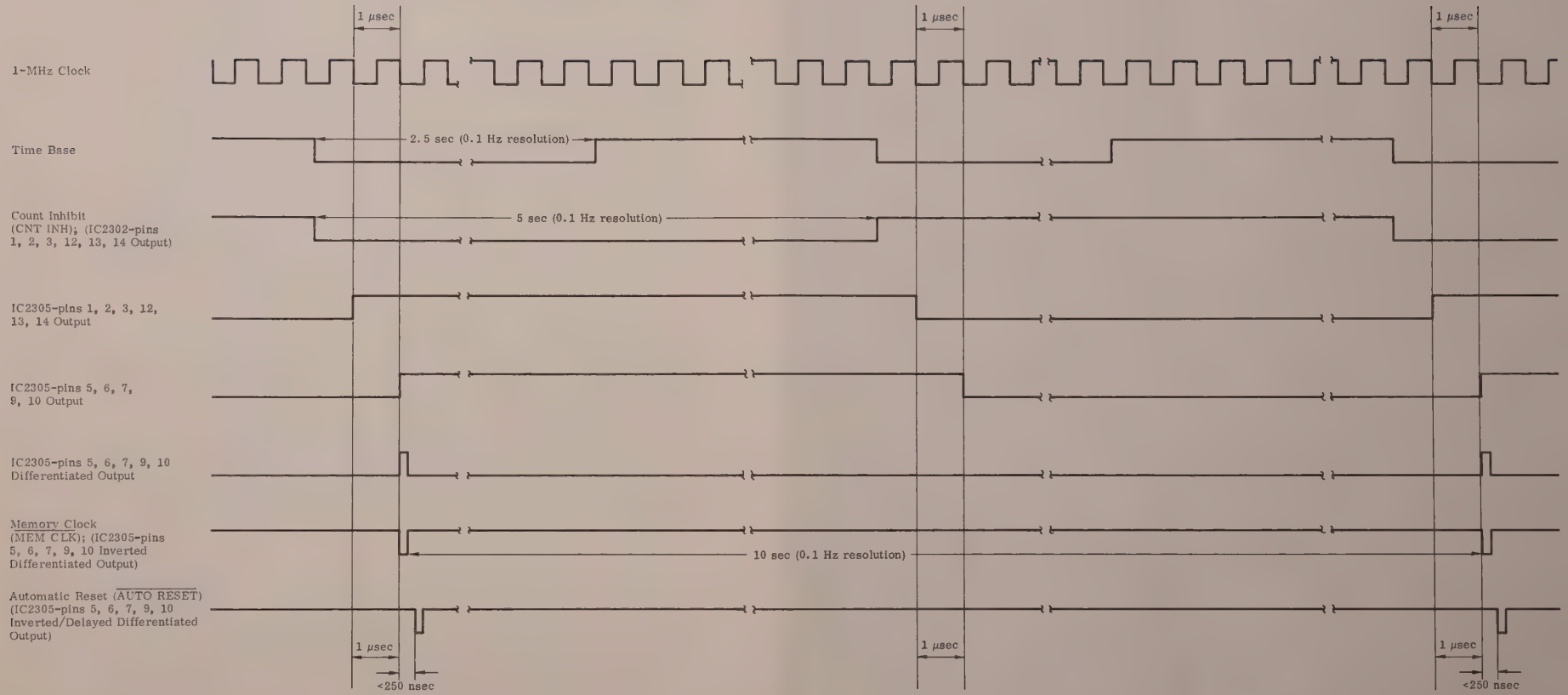

1 μsec
1 μsec
1 μsec
1-MHz Clock
Time Base
2.5 sec (0.1 Hz resolution)
Count Inhibit (CNT INH); (IC2302-pins 1, 2, 3, 12, 13, 14 Output)
5 sec (0.1 Hz resolution)
IC2305-pins 1, 2, 3, 12, 13, 14 Output
IC2305-pins 5, 6, 7, 9, 10 Output
IC2305-pins 5, 6, 7, 9, 10 Differentiated Output
Memory Clock (MEM CLK); (IC2305-pins 5, 6, 7, 9, 10 Inverted Differentiated Output)
10 sec (0.1 Hz resolution)
Automatic Reset (AUTO RESET) (IC2305-pins 5, 6, 7, 9, 10 Inverted/Delayed Differentiated Output)
1 μsec
1 μsec
1 μsec
<250 nsec
<250 nsec

Figure 4-2. Synchronizer, Timing Diagram

consist of four lines, each with a 100-Hz prf, from divider IC2308; signals from the DECE registers; and signals from switch sections S2301B or S2301C.

The decoder consists of IC2311-pins 1 through 6; IC2313-pins 1, 2, 5, 6, 10, 11; IC2316-pins 1, 2, 3, 8-13; IC2319-pins 10-13. The multiplexer consists of IC2313-pins 3, 4, 8, 9, 12, 13; IC2316-pins 4, 5, 6; IC2317-pins 8, 9, 10, 12, 13; IC2318; and IC2319-pins 8, 9.

The four lines from IC2308 are connected to the decoder, each line being energized with a 100-Hz prf signal. Each line is energized sequentially. Signals on the four lines are decoded and passed via P2301-13/P, 9/K, 11/M, and 12/N to the strobe gates and LED's. The decoder is always energized; therefore, the LED's continue to be sequentially energized, and the strobe gates continue to be sequentially enabled for the transfer of data from the storage registers to the display driver. (Since the 100-Hz lines are energized sequentially, the strobe gates and LED's are energized sequentially, rather than continuously.) The display driver, however, can only receive data if it is energized, and this is controlled by the DECE register outputs.

The DECE registers store information on the on/off status of the decade counters. When a counter is full, the DECE register associated with that counter sends a signal to the multiplexer, and the DECE signal is then multiplexed with an input from the decoder. The multiplexer output signal is gated by IC2317-pins 8, 9, 10, 12, 13 via P2301-19 to the display driver drive on board 2200. When there is no incoming DECE signal, no enabling signal is fed to the display driver drive, and the display driver is, therefore, inhibited.

Signals from switches S2301B-11 or S2301C-11 come into the multiplexer at pins 4 and 5 of IC2316, inhibiting the signal that otherwise would drive decimal point A.

4.02.03 Reset

At the end of a frequency count, all memory elements of the CE-40 are reset to zero in preparation for the next count. In addition to this automatic reset, the instrument can be manually reset by means of the front-panel RESET switch, S2401, or by means of the 0.1-Hz resolution switch button, S2301A. Manual reset overrides automatic reset regardless of what operational phase it may be in.

With reset:

* The decade counters and associated latches on boards 2400 and 2200 are reset to zero. Manual reset is used to reset these elements by triggering automatic reset. Automatic reset resets these elements when the $\overline{\text{AUTO RESET}}$ signal leaves the synchronizer in an automatic sequence of operation determined by time base selection.

* The storage registers on boards 2400 and 2200 are triggered to deposit the stored count in the strobe gates. With manual reset, a triggering signal ($\overline{\text{MAN RESET}}$ or $\overline{\text{DISP RESET}}$) is gated to the storage registers. In normal system operation, the storage registers are triggered when the $\overline{\text{MEM CLK}}$ signal is transmitted from the synchronizer on board 2300 in an automatic sequence of operation determined by time base selection.

* The decade dividers on board 2300 are reset. With manual reset, the dividers are triggered to reset by a signal produced as part of a pulse-stretching loop. (The loop is provided to eliminate contact bounce at either S2401 or S2301A.) In normal operation, these dividers are reset by gating circuits associated with each divider.

Manual reset is initiated when S2301A or S2401 is depressed, triggering the part of the pulse-stretching loop on board 2400. The switch signal is gated with another signal ($\overline{\text{MAN RESET}}$) by IC2415-pins 4, 5, 6. When S2401 is depressed, the VCC is applied to pin 5 of IC2415 via the contacts of S2401. This voltage is then gated with the $\overline{\text{MAN RESET}}$ signal, which has entered board 2400 via P2401-Z. When S2301A is depressed, this VCC is applied to pin 5 of IC2415 via S2301A-pins 8, 9, P2301-10/L and P2401-9/K (HZ DISPLAY). The $\overline{\text{MAN RESET}}$ signal is then gated with the VCC applied through S2301A instead of through S2401.

The gated signal leaves board 2400 as the ONE-SHOT RETURN signal via P2401-Y and is fed to board 2300 at P2301-21/Y. The signal is then gated by IC2319-pins 5, 6, and is fed to four destinations: (1) circuits associated with the decade dividers on board 2300; (2) the automatic reset circuits on board

2300; (3) the remainder of the pulse-stretching loop on board 2400; and (4) the storage registers on boards 2400 and 2200.

Decade Dividers. The gated signal is fed to divider IC2302 and to gating circuits associated with the other seven dividers on board 2300. These circuits provide for resetting of the dividers. The signal is fed to gate IC2314 at pin 1, associated with divider IC2315; gate IC2314 at pin 13, associated with divider IC2312; gate IC2311 at pin 9, associated with divider IC2310; gate IC2309 at pin 13, associated with divider IC2308; gate IC2307 at pin 1, associated with divider IC2306; gate IC2303 at pin 5, associated with divider IC2304; gate IC2303 at pin 9, associated with divider IC2301; and flip-flop IC2302 at pin 6.

Automatic Reset Circuits. The gated signal is also fed to IC2302 at pin 2 and to IC2307 at pin 9, thereby triggering the automatic reset circuits. After a one time-base time delay, the $\overline{\text{AUTO RESET}}$ signal is sent from the automatic reset circuits via P2301-16/T and P2401-15/S to the LSD, 3rd MSD and 2nd MSD decades and associated latches on board 2400; and via P2301-16/T and P2201-T to the MSD decade and associated latch on board 2200.

Pulse-Stretching Loop. The gated signal is also fed as the $\overline{\text{MAN RESET}}$ signal via P2301-22/Z to board 2400 at P2401-Z. The signal then travels to IC2415 at pin 4 where it is gated with the VCC from S2401 or S2301A, thus completing the pulse-stretching loop.

Storage Registers. In addition to being used to complete the pulse-stretching loop, the $\overline{\text{MAN RESET}}$ signal, after reentering board 2400 at P2401-Z, is delayed 100 ns by R2401 and C2401 and is then gated to the storage registers on board 2400 and 2200. The 100-ns delay is used to ensure that the storage registers are cleared of the previous count. The delayed signal is gated via IC2415-pins 1, 2, 3, to the LSD and 3rd MSD storage registers, and via IC2415-pins 11, 12, 13 to the 2nd MSD storage register. The delayed signal is also fed via P2401-22 as the $\overline{\text{DISP RESET}}$ signal to board 2200 at P2201-22 and is gated via IC2204-pins 4, 5, 6 to the MSD storage register.

As mentioned earlier, in normal system operation, the storage registers are triggered by the $\overline{\text{MEM CLK}}$ signal. Thus, it can be seen that the $\overline{\text{MEM CLK}}$ signal serves as the normal operational counterpart of the manual reset $\overline{\text{MAN RESET}}$ signal. Accordingly, the integrated circuits used to gate the $\overline{\text{MAN RESET}}$

signal to the storage registers are the same integrated circuits used to gate the $\overline{\text{MEM CLK}}$ signal to the storage registers.

4.02.04 Self-Testing

Two signals are used to initiate testing of the instrument's counting and timing circuits -- the signal activated by depressing the front-panel CHECK switch, S2402, and the 1-kHz signal produced at the output of decade divider IC2306 on board 2300.

When CHECK switch S2402 is depressed, the VCC is applied via its contacts and P2401-13/P to diode CR2003 on board 2000. This signal, a 5.5-volt signal, causes Q2001 to switch off the input signal and permits the 1-kHz signal from IC2306 to be amplified. The 1-kHz signal is always present and passes through diodes CR2006 and CR2007 to the input amplifier, but is limited by CR2003 to 0.2v until S2402 provides the 5-volt input to disable the input signal.

The 1-kHz CHECK signal then follows the same path as the main input signal, resulting in a 1-kHz display.

4.02.05 ON/OFF Switch

The ON and OFF switch pushbuttons, S2403B and S2403A, are mechanically ganged together such that depressing one button automatically releases the other. When the ON switch button is depressed, the 5.5 volts supplied by the battery is connected to the VCC buss enabling only those circuits on boards 2000 and 2200. The other circuit elements are energized only when they are about to be required.

4.02.06 Power Supply

The CE-40 can be operated by internally-mounted batteries or by using an external power source. On the regulator/charger board (printed circuit board 3100), unregulated ac voltage is converted to regulated dc voltage. Power is supplied from the batteries or from an external 117 vac 50-400 Hz power source. The input voltage is applied to rear panel plug P3001, is stepped down by transformer T3001 to 15V rms center-tapped, and is passed to board 3100 at WT 3101, WT 3102, and WT 3103. The output voltage is 5.5v at 400 ma.

SECTION 5

MAINTENANCE

This section will be included
in the final manual.

SECTION 6

SCHEMATICS AND PARTS LISTS

6.01 SCHEMATICS

The schematics for the CE-40 are provided at the end of this manual. The drawings have been arranged according to the circuit reference series numbers shown in the lower right-hand corner of the page.

6.02 PARTS LISTS

The parts lists for the CE-40 are provided on the following pages. These lists have been arranged according to the circuit reference series numbers shown in the upper right-hand corner of each page.

6.02.01 FRONT PANEL

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
1000	Board Assy., Front Panel	7003-0038	Cushman		
	Front Panel	2800-0052	Cushman		
	CAPACITOR				
C1	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
	JACK				
J1	3-Conductor, Single Circuit, Audio	2586-0011	Switchcraft	113B	

6.02.02 MOTHER BOARD

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
2000	Board Assy., Mother	7001-0099	Cushman		
	Board, Printed Circuit	1780-0226	Cushman		
	CAPACITORS				
C1	Poly, 0.39 μF ±10%, 200V	1008-0037	Electrocube	625B1C394K2	
C2	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
C3	Tant, 10 μF ±10%, 20V	1011-0007	Kemet	K10C20K	
C4	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
C5	Elect., 500 μF ±10%, 15V	1013-0014	San Fernando	15.501	
C6	Tant, 10 μF ±10%, 20V	1011-0007	Kemet	K10C20K	
C7	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
C8	Polyester Film, 0.0012 μF ±10%, 100V	1008-0016	Sprague	225P12291WA3	
C9	Polyester Film, 0.012 μF ±10%, 100V	1008-0040	Sprague	225P12391WA3	
C10	Elect., 1.5 μF ±10%, 35V	1013-0001	Sprague	150D155X9035B2	
C11	Elect., 500 μF ±10%, 15V	1013-0014	San Fernando	15.501	
C12	Elect., 350 μF +150% -10%, 3V	1013-0023	Syncro	EMW-1228-350-3	
C13	Mica, 22 pF ±50%, 500V	1002-0023	Elmenco	DM15-C-220J	
	CONNECTORS				
J1	22-pin Connector, Double Row	2535-0034	Viking	2VH22/1AV5	
J2	22-pin Connector, Double Row	2535-0034	Viking	2VH22/1AV5	
J3	22-pin Connector, Double Row	2535-0034	Viking	2VH22/1AV5	
	DIODES				
CR1	Hot Carrier	1283-0001	HPA	H-P 5082-2800	
CR2	Hot Carrier	1283-0001	HPA	H-P 5082-2800	
CR3	Hot Carrier	1283-0001	HPA	H-P 5082-2800	
CR4	Hot Carrier	1283-0001	HPA	H-P 5082-2800	

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
CR5	Hot Carrier	1283-0001	HPA	H-P 5082-2800	
CR6	Si, High Speed	1281-0013	Transitron	1N3064	
CR7	Si, High Speed	1281-0013	Transitron	1N3064	
	RESISTORS				
R1	Comp, 10kΩ ±5%, 1/4W	1066-1035	Allen-Bradley	Type CB	
R2	Comp, 1kΩ ±5%, 1/4W	1066-1025	Allen-Bradley	Type CB	
R3	Comp, 100kΩ ±5%, 1/4W	1066-1045	Allen-Bradley	Type CB	
R4	Comp, 33kΩ ±5%, 1/4W	1066-3335	Allen-Bradley	Type CB	
R5	Comp, 47kΩ ±5%, 1/4W	1066-4735	Allen-Bradley	Type CB	
R6	Comp, 22kΩ ±5%, 1/4W	1066-2235	Allen-Bradley	Type CB	
R7	Comp, 4.7kΩ ±5%, 1/4W	1066-4725	Allen-Bradley	Type CB	
R8	Comp, 220Ω ±5%, 1/4W	1066-2215	Allen-Bradley	Type CB	
R9	Comp, 22kΩ ±5%, 1/4W	1066-2235	Allen-Bradley	Type CB	
R10	Comp, 1kΩ ±5%, 1/4W	1066-1025	Allen-Bradley	Type CB	
R11	Comp, 10Ω ±5%, 1/4W	1066-1005	Allen-Bradley	Type CB	
R12	Comp, 680Ω ±5%, 1/4W	1066-6815	Allen-Bradley	Type CB	
R13	Comp, 3.3kΩ ±5%, 1/4W	1066-3325	Allen-Bradley	Type CB	
R14	Comp, 5.6kΩ ±5%, 1/4W	1066-5625	Allen-Bradley	Type CB	
R15	Comp, 220Ω ±5%, 1/4W	1066-2215	Allen-Bradley	Type CB	
R16	Comp, 1kΩ ±5%, 1/4W	1066-1025	Allen-Bradley	Type CB	
	TRANSISTORS				
Q1	Si, P Channel FET	1272-0050	Siliconix	VCR6P	
Q2	Si, NPN	1272-0017	Fairchild	2N3565	
Q3	Si, PNP	1272-0024	Fairchild	2N4249	
Q4	Si, NPN	1272-0016	Fairchild	2N4275	

6.02.03 LIGHT-EMITTING DIODE (LED)

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
2100	Board Assy., Light-Emitting Diode	7001-0098	Cushman		
	Board, Printed Circuit	1780-0225	Cushman		
	DIODES				
CR1	Light-Emitting Diode	1281-0041	Monsanto	MV10B	
CR2	Light-Emitting Diode	1281-0041	Monsanto	MV10B	
CR3	Light-Emitting Diode	1281-0041	Monsanto	MV10B	
CR4	Light-Emitting Diode	1281-0041	Monsanto	MV10B	
LED1	Alpha-Numeric Segment Readout	1281-0039	Lytronics	DATA-LIT 10A	
LED2	Alpha-Numeric Segment Readout	1281-0039	Lytronics	DATA-LIT 10A	
LED3	Alpha-Numeric Segment Readout	1281-0039	Lytronics	DATA-LIT 10A	
LED4	Alpha-Numeric Segment Readout	1281-0039	Lytronics	DATA-LIT 10A	
	RESISTOR				
R1	Comp, 8.2kΩ ±5%, 1/4W	1066-8225	Allen-Bradley	Type CB	

6.02.04 DISPLAY

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
2200	Board Assy., Display	7001-0097	Cushman		
	Board, Printed Circuit	1780-0224	Cushman		
	CAPACITORS				
C1	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
C2	Mica, 33 pF ±5%, 500V	1002-0024	Elmenco	DM15-E-330J	
C3	Mica, 33 pF ±5%, 500V	1002-0024	Elmenco	DM15-E-330J	
C4	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
	CONNECTOR				
J1	30-pin Connector	2535-0033	Cinch	252-15-30-300	
	DIODES				
CR1	Zener, 3.6V	1281-0045	Motorola	1N4729A	
CR2	Si, High Speed	1281-0013	Transitron	1N3064	
CR3	Si, High Speed	1281-0013	Transitron	1N3064	
	INTEGRATED CIRCUITS				
IC1	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC2	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC3	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC4	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC5	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC6	TTL Four-Bit Binary Counter	2025-0044	T.I.	SN25493N	

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
IC7	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC8	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC9	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC10	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC11	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC12	TTL BCD-to-Seven-Segment Decoder Driver	2025-0035	T.I.	SN7447N	
	RESISTORS				
R1	Comp, 470Ω ±5%, 1/8W	1065-4715	Allen-Bradley	Type BB	
R2	Comp, 68kΩ ±5%, 1/8W	1065-6835	Allen-Bradley	Type BB	
R3	Comp, 3.9kΩ ±5%, 1/8W	1065-3925	Allen-Bradley	Type BB	
R4	Comp, 470Ω ±5%, 1/8W	1065-4715	Allen-Bradley	Type BB	
R5	Pot, Cer, Met, 5kΩ ±10%, 1/2W	1200-0021	Helitrim	62P-R5K	
R6	Comp, 3.9kΩ ±5%, 1/8W	1065-3925	Allen-Bradley	Type BB	
R7	Comp, 470Ω ±5%, 1/8W	1065-4715	Allen-Bradley	Type BB	
R8	Comp, 2.7kΩ ±5%, 1/8W	1065-2725	Allen-Bradley	Type BB	
R9	Comp, 470Ω ±5%, 1/8W	1065-4715	Allen-Bradley	Type BB	
R10	Comp, 1kΩ ±5%, 1/8W	1065-1025	Allen-Bradley	Type BB	
R11	Comp, 1.8kΩ ±5%, 1/8W	1065-1825	Allen-Bradley	Type BB	
R12	Comp, 2.2kΩ ±5%, 1/8W	1065-2225	Allen-Bradley	Type BB	
R13	Comp, 22kΩ ±5%, 1/8W	1065-2235	Allen-Bradley	Type BB	
R14	Comp, 470Ω ±5%, 1/8W	1065-4715	Allen-Bradley	Type BB	
R15	Comp, 1.8kΩ ±5%, 1/8W	1065-1825	Allen-Bradley	Type BB	
R16	Comp, 2.2kΩ ±5%, 1/8W	1065-2225	Allen-Bradley	Type BB	
R17	Comp, 3.9kΩ ±5%, 1/8W	1065-3925	Allen-Bradley	Type BB	

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
R18	Comp, 3.9kΩ ±5%, 1/8W	1065-3925	Allen-Bradley	Type BB	
R19	Comp, 1.8kΩ ±5%, 1/8W	1065-1825	Allen-Bradley	Type BB	
R20	Comp, 2.2kΩ ±5%, 1/8W	1065-2225	Allen-Bradley	Type BB	
R21	Comp, 1.8kΩ ±5%, 1/8W	1065-1825	Allen-Bradley	Type BB	
R22	Comp, 2.2kΩ ±5%, 1/8W	1065-2225	Allen-Bradley	Type BB	
R23	Comp, 2.7kΩ ±5%, 1/8W	1065-2725	Allen-Bradley	Type BB	
R24	Comp, 2.7kΩ ±5%, 1/8W	1065-2725	Allen-Bradley	Type BB	
R25	Comp, 3.9kΩ ±5%, 1/8W	1065-3925	Allen-Bradley	Type BB	
R26	Comp, 3.9kΩ ±5%, 1/8W	1065-3925	Allen-Bradley	Type BB	
R27	Comp, 22Ω ±5%, 1/8W	1065-2205	Allen-Bradley	Type BB	
R28	Comp, 22Ω ±5%, 1/8W	1065-2205	Allen-Bradley	Type BB	
R29	Comp, 22Ω ±5%, 1/8W	1065-2205	Allen-Bradley	Type BB	
R30	Comp, 22Ω ±5%, 1/8W	1065-2205	Allen-Bradley	Type BB	
R31	Comp, 22Ω ±5%, 1/8W	1065-2205	Allen-Bradley	Type BB	
R32	Comp, 22Ω ±5%, 1/8W	1065-2205	Allen-Bradley	Type BB	
R33	Comp, 22Ω ±5%, 1/8W	1065-2205	Allen-Bradley	Type BB	
R34	Comp, 470Ω ±5%, 1/8W	1065-4715	Allen-Bradley	Type BB	
R35	Comp, 2.7kΩ ±5%, 1/8W	1065-2725	Allen-Bradley	Type BB	
R36	Not Used				
R37	Not Used				
R38	Comp, 3.9kΩ ±5%, 1/8W	1065-3925	Allen-Bradley	Type BB	
R39	Comp, 470Ω ±5%, 1/8W	1065-4715	Allen-Bradley	Type BB	
	TRANSISTORS				
Q1	Si, PNP	1272-0023	Fairchild	2N4121	
Q2	Si, NPN	1272-0016	Fairchild	2N4275	
Q3	Si, PNP	1272-0040	Fairchild	2N3644	
Q4	Si, NPN	1272-0016	Fairchild	2N4275	
Q5	Si, PNP	1272-0040	Fairchild	2N3644	

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
Q6	Si, PNP	1272-0040	Fairchild	2N3644	
Q7	Si, PNP	1272-0040	Fairchild	2N3644	
Q8	Si, PNP	1272-0023	Fairchild	2N4121	
Q9	Si, PNP	1272-0023	Fairchild	2N4121	
Q10	Si, NPN	1272-0016	Fairchild	2N4275	
Q11	Not Used				
Q12	Si, NPN	1272-0016	Fairchild	2N4275	

6.02.05 TIME BASE

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
2300	Board Assy., Time Base	7001-0096	Cushman		
	Board, Printed Circuit	1780-0222	Cushman		
	CAPACITORS				
C1	Cer, 30 pF ±5%, 100V	1005-0072	Erie	805-024-C0G-330J	
C2	Trimmer, Cer, 2-8 pF, 350V	1001-0004	Erie	538-002A-2-8	
C3	Mica, 1000 pF ±5%, 100V	1002-0015	Elmenco	DM15-F-102J	
C4	Mica, 1000 pF ±5%, 100V	1002-0015	Elmenco	DM15-F-102J	
C5	Polyester Film, 0.1 μF ±10%, 100V	1008-0031	Sprague	225P10491WA3	
C6	Cer, 22 pF ±5%, 100V	1005-0066	Erie	835-NPO	
C7	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C8	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C9	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C10	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C11	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C12	Mica, 51 pF ±5%, 500V	1002-0045	Elmenco	DM15-E-510J	
C13	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C14	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C15	Elect, 1.5 μF ±10%, 100V	1013-0001	Sprague	150D155X9035B2	
C16	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
	CRYSTAL				
Y1	2-MHz Crystal	2035-0008	Cushman		
	DIODE				
CR1	Si, High Speed	1281-0013	Transitron	1N3064	

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
	INTEGRATED CIRCUITS				
IC1	TTL Four-Bit Binary Counter	2025-0044	T. I.	SN25493N	
IC2	TTL Dual J-K Master Slave Flip-Flop	2025-0041	T. I.	SN74L73N	
IC3	TTL Quad 2-Input Positive NAND Gate	2025-0036	T. I.	SN74L00N	
IC4	TTL Four-Bit Binary Counter	2025-0044	T. I.	SN25493N	
IC5	TTL Dual J-K Master-Slave Flip-Flop	2025-0041	T. I.	SN74L73N	
IC6	TTL Four-Bit Binary Counter	2025-0044	T. I.	SN25493N	
IC7	TTL Quad 2-Input Positive NAND Gate	2025-0036	T. I.	SN74L00N	
IC8	TTL Four-Bit Binary Counter	2025-0044	T. I.	SN25493N	
IC9	TTL Quad 2-Input Positive NAND Gate	2025-0036	T. I.	SN74L00N	
IC10	TTL Four-Bit Binary Counter	2025-0044	T. I.	SN25493N	
IC11	TTL Quad 2-Input Positive NAND Gate	2025-0036	T. I.	SN74L00N	
IC12	TTL Four-Bit Binary Counter	2025-0044	T. I.	SN25493N	
IC13	TTL Hex Inverter	2025-0038	T. I.	SN74L04N	
IC14	TTL Quad 2-Input Positive NAND Gate	2025-0036	T. I.	SN74L00N	
IC15	TTL Four-Bit Binary Counter	2025-0044	T. I.	SN25493N	
IC16	TTL Quad 2-Input Positive NAND Gate	2025-0036	T. I.	SN74L00N	
IC17	TTL Dual 4-Input NAND Gate	2025-0040	T. I.	SN74L20N	
IC18	TTL Triple 3-Input NAND Gate	2025-0039	T. I.	SN74L10N	
IC19	TTL Hex Inverter	2025-0038	T. I.	SN74L04N	
	RESISTORS				
R1	Comp, 10kΩ ±5%, 1/4W	1066-1035	Allen-Bradley	Type CB	
R2	Comp, 1kΩ ±5%, 1/4W	1066-1025	Allen-Bradley	Type CB	
R3	Comp, 560Ω ±5%, 1/4W	1066-5615	Allen-Bradley	Type CB	
R4	Comp, 10kΩ ±5%, 1/4W	1066-1035	Allen-Bradley	Type CB	
R5	Comp, 1kΩ ±5%, 1/4W	1066-1025	Allen-Bradley	Type CB	
R6	Comp, 22kΩ ±5%, 1/4W	1066-2235	Allen-Bradley	Type CB	

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
R7	Comp, 5.6kΩ ±5%, 1/4W	1066-5625	Allen-Bradley	Type CB	
R8	Comp, 3.9kΩ ±5%, 1/4W	1066-3925	Allen-Bradley	Type CB	
R9	Comp, 3.9kΩ ±5%, 1/4W	1066-3925	Allen-Bradley	Type CB	
	SWITCH				
S1	4-Station Pushbutton	1852-0009	Cushman	PB15-Series	
	TRANSISTORS				
Q1	Si, NPN	1272-0022	Fairchild	2N3563	
Q2	Si, NPN	1272-0016	Fairchild	2N4275	

6.02.06 COUNTER

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
2400	Board Assy., Counter	7001-0096	Cushman		
	Board, Printed Circuit	1780-0223	Cushman		
	CAPACITORS				
C1	Cer, .01 μF ±10%, 100V	1005-0065	Aerovox	CK06BX103K	
C2	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
C3	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C4	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
C5	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
C6	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
C7	Mica, 220 pF ±5%, 500V	1002-0029	Elmenco	DM15-F-221J	
	INTEGRATED CIRCUITS				
IC1	TTL Four-Bit Binary Counter	2025-0044	T.I.	SN25493N	
IC2	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC3	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC4	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC5	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC6	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC7	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC8	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC9	TTL Four-Bit Binary Counter	2025-0044	T.I.	SN25493N	
IC10	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	

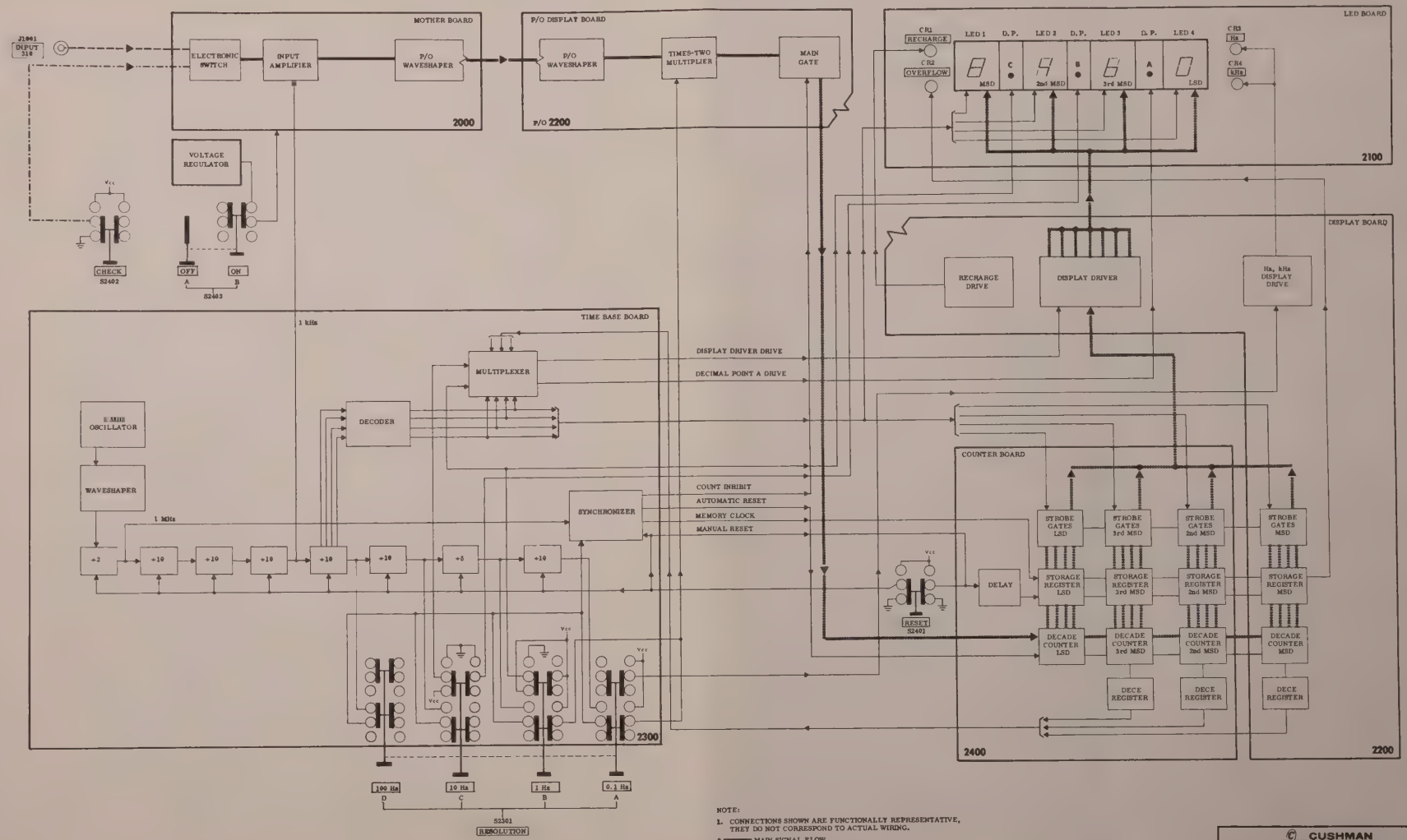
CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
IC11	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC12	TTL Four-Bit Binary Counter	2025-0044	T.I.	SN25493N	
IC13	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC14	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC15	TTL Quad 2-Input Positive NAND Gate	2025-0036	T.I.	SN74L00N	
IC16	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC17	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
IC18	TTL Dual D-Type Edge-Triggered Flip-Flop	2025-0042	T.I.	SN74L74N	
	RESISTORS				
R1	Comp, 1kΩ ±5%, 1/4W	1066-1025	Allen-Bradley	Type CB	
R2	Comp, 10kΩ ±5%, 1/4W	1066-1035	Allen-Bradley	Type CB	
R3	Comp, 3.9kΩ ±5%, 1/4W	1066-3925	Allen-Bradley	Type CB	
	SWITCH				
S1, S2, S3	4-Station Pushbutton	1852-0010	Cushman	PB15-Series	

6.02.07 REAR PANEL

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
3000	Board Assy., Rear Panel	7003-0039	Cushman		
	Rear Panel	2800-0053	Cushman		
	BATTERY				
BT1	5.5V	1046-0003	Cushman		
	CAPACITOR				
C1	Cer, 0.05 μF +80 -20%, 500V	1005-0052	Sprague	5HK-S50	
	FUSES				
F1	Slo-Blo, 1/8 Amp	1955-0014	Littelfuse	3AG-313125	
F2	Slo-Blo, 1 Amp	1955-0006	Littelfuse	3AG-313001	
	FUSEHOLDERS				
	Low Profile	1965-0011	Littelfuse	348-8-9-9	
	Low Profile	1965-0011	Littelfuse	348-8-9-9	
	PLUG				
P1	Receptacle, Recessed, AC	2535-0030	Switchcraft	LAC3G	
	TRANSISTOR				
Q1	Si, PNP	1272-0049	Motorola	MJE-371	
	TRANSFORMER				
T1	Power, 15.0V RMS, 1 Amp	1575-0012	Tranex	4-2639-1	
	PC BOARD ASSEMBLY				
3100	Regulator/Charger	7001-0100	Cushman		

6.02.08 REGULATOR/CHARGER

CKT. REF.	DESCRIPTION	CE STOCK NO.	MFR.	MFR. NO.	$
3100	Board Assy., Regulator/Charger	7001-0100	Cushman		
	Board, Printed Circuit	1780-0227	Cushman		
	CAPACITORS				
C1	Elect., 6500 μF +15 -10%, 15V	1013-0024	Syncro	EMW-3268-6500-15	
C2	Cer, 0.1 μF ±10%, 100V	1005-0064	Aerovox	CK06BX104K	
	DIODES				
CR1	Si, Rectifier	1281-0023	ITT	1N4002	
CR2	Si, Rectifier	1281-0023	ITT	1N4002	
CR3	Si, Zener 5.6V, 0.4W	1281-0042	Motorola	1N752A	
CR4	Si, Rectifier	1281-0023	ITT	1N4002	
	RESISTORS				
R1	Comp, 1.5Ω ±5%, 1/2W	1067-0002	Allen-Bradley	Type EB	
R2	Comp, 560Ω ±5%, 1/4W	1066-5615	Allen-Bradley	Type CB	
R3	Comp, 270kΩ ±5%, 1/4W	1066-2745	Allen-Bradley	Type CB	
R4	Comp, 151Ω ±5%, 1/4W	1066-1535	Allen-Bradley	Type CB	
R5	Comp, 100Ω ±5%, 1/4W	1066-1015	Allen-Bradley	Type CB	
R6	Comp, 56Ω ±5%, 1/4W	1066-5605	Allen-Bradley	Type CB	
R7	Comp, 18Ω ±5%, 1/4W	1066-1805	Allen-Bradley	Type CB	
	TRANSISTORS				
Q1	Si, PNP	1272-0023	Fairchild	2N4121	
Q2	Si, NPN	1272-0014	Fairchild	2N3567	
Q3	Si, NPN	1272-0017	Fairchild	2N3565	



NOTE:

1. CONNECTIONS SHOWN ARE FUNCTIONALLY REPRESENTATIVE, THEY DO NOT CORRESPOND TO ACTUAL WIRING.
2. ——— MAIN SIGNAL FLOW.
3. — — — INPUT SIGNAL FLOW.
4. — · — · — SELF-TESTING SIGNAL FLOW.

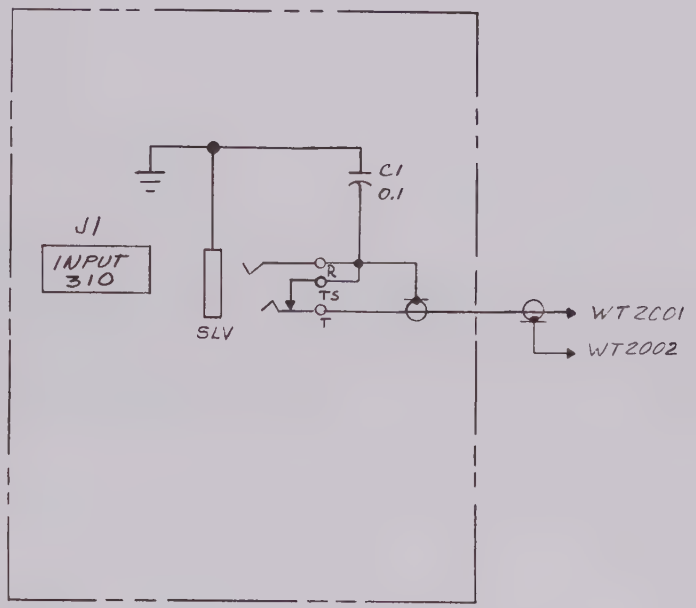
CUSHMAN ELECTRONICS INC.

SCALE	APPROVED BY:	DRAWN BY VLD
DATE: 4-2-71	7-14-71	REVISED

CE-40 OVERALL BLOCK DIAGRAM

DRAWING NUMBER 3540000

	REVISIONS		
LTR	DESCRIPTION	DATE	APPROVED



NOTE:

1. RESISTORS - 1/4W, 5% VALUES IN OHMS UNLESS OTHERWISE NOTED.
2. CAPACITORS - VALUES IN μF UNLESS OTHERWISE NOTED.
3. INDUCTORS - VALUES IN μH UNLESS OTHERWISE NOTED.
4. *FACTORY SELECT. TYPICAL VALUE SHOWN.
5. ALL VOLTAGES ARE DC UNLESS OTHERWISE NOTED.
6. ALL FRONT PANEL CONTROLS ARE MOUNTED ON INDIVIDUAL PC BOARDS.

CIRCUIT REFERENCE SERIES: 1000

CIRCUIT REFERENCE USED:			
C(100)1 - C( )		Q( ) - Q( )	
CR( ) - CR( )		R( ) - R( )	
DS( ) - DS( )		S( ) - S( )	
F( ) - F( )		T( ) - T( )	
IC( ) - IC( )		Y( ) - Y( )	
L( ) - L( )		J(100)1	

CUSHMAN ELECTRONICS, INC.

SCALE:	APPROVED BY: 2-11-71 SS 7-14-71	DRAWN BY VLC
DATE: 1-20-71		REVISED

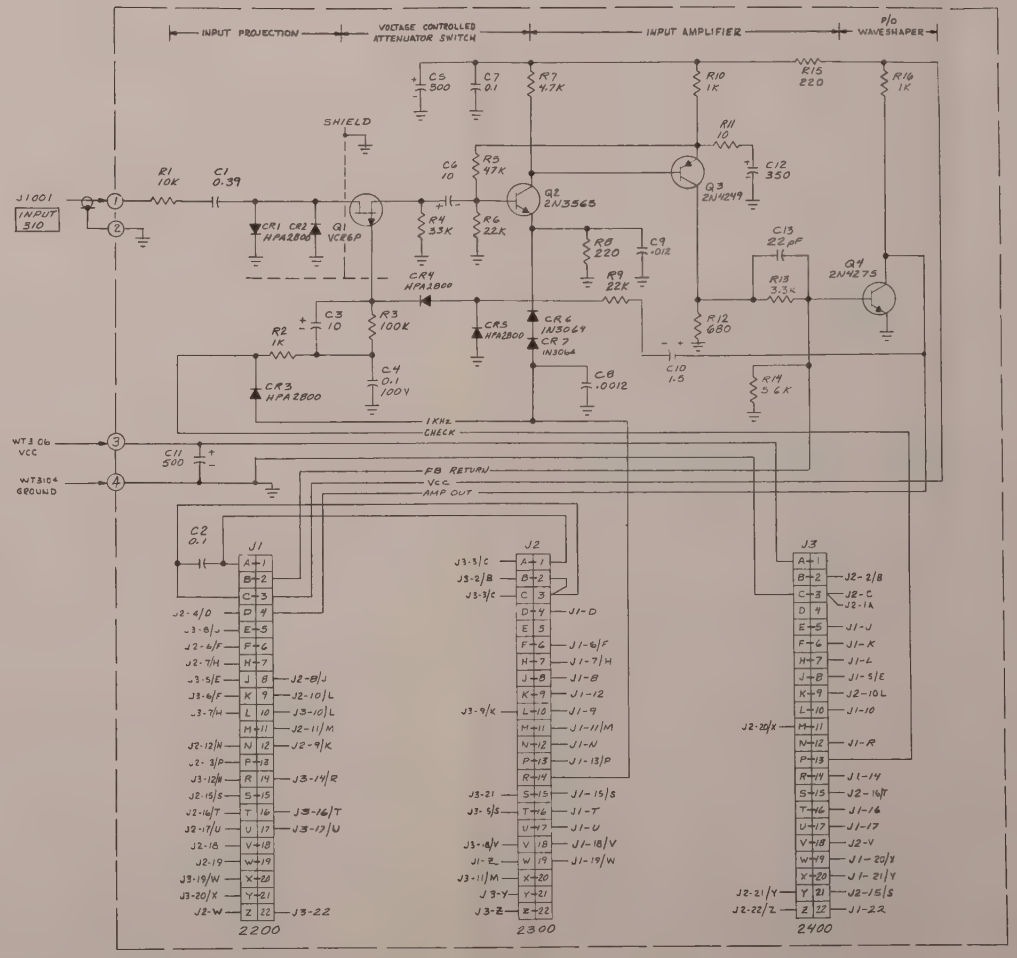
FRONT PANEL, ASSEMBLY 7001-0038

40 - 1000

DRAWING NUMBER 3540001

11X17 PRINTED ON NO. 1000H-10 CLEARPRINT FADE-OUT

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	EC-13	7-14-71	



NOTE:

1. RESISTORS - 1/4W, 5% VALUES IN OHMS UNLESS OTHERWISE NOTED.
2. CAPACITORS - VALUES IN μF UNLESS OTHERWISE NOTED.
3. INDUCTORS - VALUES IN μH UNLESS OTHERWISE NOTED.
4. *FACTORY SELECT. TYPICAL VALUE SHOWN.
5. ALL VOLTAGES ARE DC UNLESS OTHERWISE NOTED.

CIRCUIT REFERENCE SERIES: 2000

CIRCUIT REFERENCE USED:			
C(2001 - C(2003		Q(2001 - Q(2014	
CR(2001 - CR(2007		R(2001 - R(2016	
DS( ) - DS( )		S( ) - S( )	
FE( ) - FE( )		T( ) - T( )	
IC( ) - IC( )		Y( ) - Y( )	
L( ) - L( )		J(2001 - J(2003	

CUSHMAN ELECTRONICS, INC.

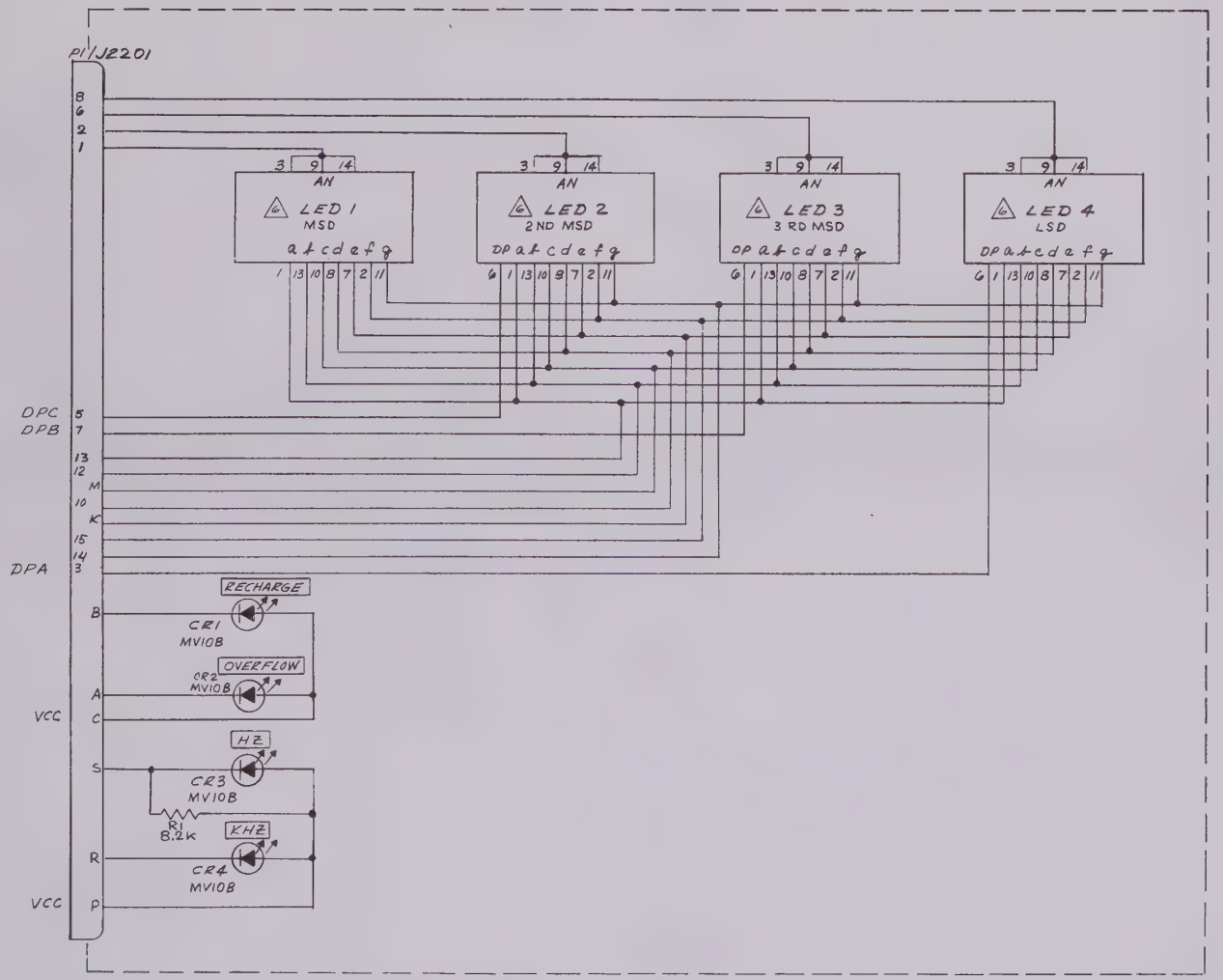
SCALE:	APPROVED BY: 2-11-71	DRAWN BY: WD
DATE: 11-19-70	7-14-71	REVISED

MOTHER BOARD, PC BOARD ASSEMBLY 7001-0099

40-2000

DRAWING NUMBER 3540226

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



NOTE:

1. RESISTORS - 1/4W, 5% VALUES IN OHMS UNLESS OTHERWISE NOTED.
2. CAPACITORS - VALUES IN μF UNLESS OTHERWISE NOTED.
3. INDUCTORS - VALUES IN μH UNLESS OTHERWISE NOTED.
4. *FACTORY SELECT. TYPICAL VALUE SHOWN.
5. ALL VOLTAGES ARE DC UNLESS OTHERWISE NOTED.

6. DIODE ARRANGEMENT IN LED'S IS f/a/b c/g/d

CIRCUIT REFERENCE SERIES: 2100

CIRCUIT REFERENCE USED:	
C( ) - C( )	Q( ) - Q( )
CR(210)1 - CR(210)4	R(210)1
DS( ) - DS( )	S( ) - S( )
F( ) - F( )	T( ) - T( )
IC( ) - IC( )	Y( ) - Y( )
L( ) - L( )	LED(210)1 - LED(210)4

CUSHMAN ELECTRONICS, INC.

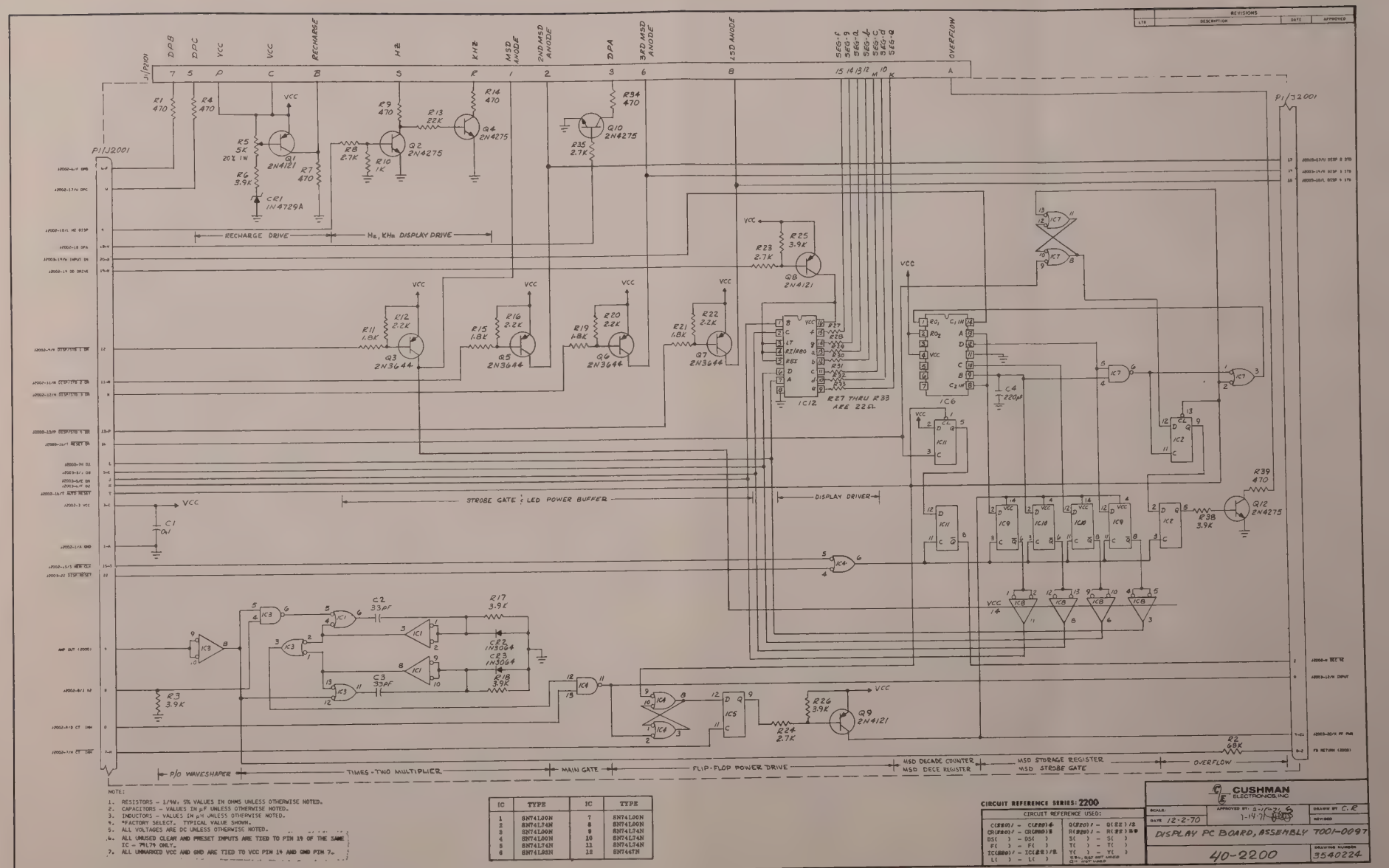
SCALE:	APPROVED BY: 2-11-71 7-14-71	DRAWN BY C. R.
DATE: 11-24-70		REVISED

LIGHT-EMITTING DIODE PC BOARD, ASSY 7001-0098

40-2100

DRAWING NUMBER 3540225

17X22 PRINTED ON NO. 1000H-10 CLEARPRINT



NOTE:
1. RESISTORS – 1/4W, 5% VALUES IN OHMS UNLESS OTHERWISE NOTED.
2. CAPACITORS – VALUES IN μF UNLESS OTHERWISE NOTED.
3. INDUCTORS – VALUES IN μH UNLESS OTHERWISE NOTED.
4. *FACTORY SELECT. TYPICAL VALUE SHOWN.
5. ALL VOLTAGES ARE DC UNLESS OTHERWISE NOTED.
6. ALL UNUSED CLEAR AND PRESET INPUTS ARE TIED TO PIN 14 OF THE SAME IC – 74L79 ONLY.
7. ALL UNMARKED VCC AND GND ARE TIED TO VCC PIN 14 AND GND PIN 7.

IC	TYPE	IC	TYPE
1	SN74L00N	7	SN74L00N
2	SN74L74N	8	SN74L00N
3	SN74L00N	9	SN74L74N
4	SN74L00N	10	SN74L74N
5	SN74L74N	11	SN74L74N
6	SN74L83N	12	SN7447N

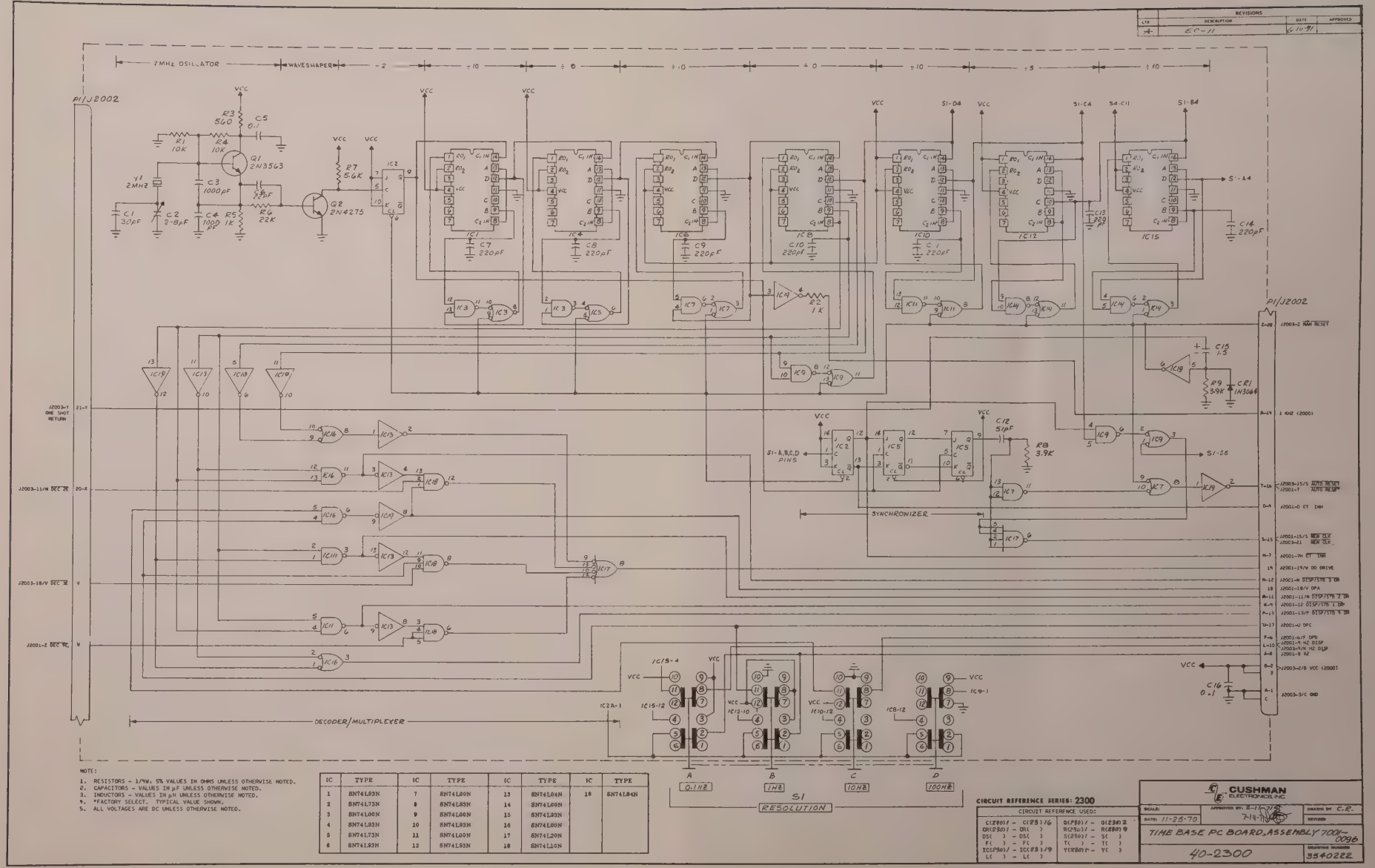
CIRCUIT REFERENCE SERIES: 2200

CIRCUIT REFERENCE USED:

C(ES01) = C(ES0)6 — Q(ES2) = Q(ES2)12
CR(ES0) = CR(ES0)5 — R(ES2) = R(ES2)8
DSC ( ) = DSC ( ) — SL ( ) = SL ( )
FC ( ) = FC ( ) — TC ( ) = TC ( )
IC(ES0) = IC(ES2)12 — YC ( ) = YC ( )
LC ( ) = LC ( )

CUSHMAN ELECTRONICS, INC

SCALE:	APPROVED BY: 2-1-71 1-14-71
DATE 12-2-70	DRAWN BY C.R
	REVISED
DISPLAY PC BOARD, ASSEMBLY T001-0097	
40-2200	DRAWING NUMBER 3540224



NOTE:
1. RESISTORS - 1/4W, 5% VALUES IN OHMS UNLESS OTHERWISE NOTED.
2. CAPACITORS - VALUES IN μF UNLESS OTHERWISE NOTED.
3. INDUCTORS - VALUES IN μH UNLESS OTHERWISE NOTED.
4. *FACTORY SELECT. TYPICAL VALUE SHOWN.
5. ALL VOLTAGES ARE DC UNLESS OTHERWISE NOTED.

IC	TYPE	IC	TYPE	IC	TYPE	IC	TYPE
1	SN74L93N	7	SN74L00N	13	SN74L04N	19	SN74L84N
2	SN74L73N	8	SN74L93N	14	SN74L00N		
3	SN74L00N	9	SN74L00N	15	SN74L93N		
4	SN74L93N	10	SN74L93N	16	SN74L00N		
5	SN74L73N	11	SN74L00N	17	SN74L20N		
6	SN74L93N	12	SN74L93N	18	SN74L10N		

CIRCUIT REFERENCE SERIES: 2300

CIRCUIT REFERENCE USED:

C(2X0)/ - C(23)/6
CR(2X0)/ - CR( )
DS( ) - DS( )
F( ) - F( )
IC(2X0)/ - IC(23)/9
L( ) - L( )
Q(2X0)/ - Q(2X0)2
R(2X0)/ - R(2X0)9
S(2X0)/ - S( )
T( ) - T( )
Y(2X0)/ - Y( )

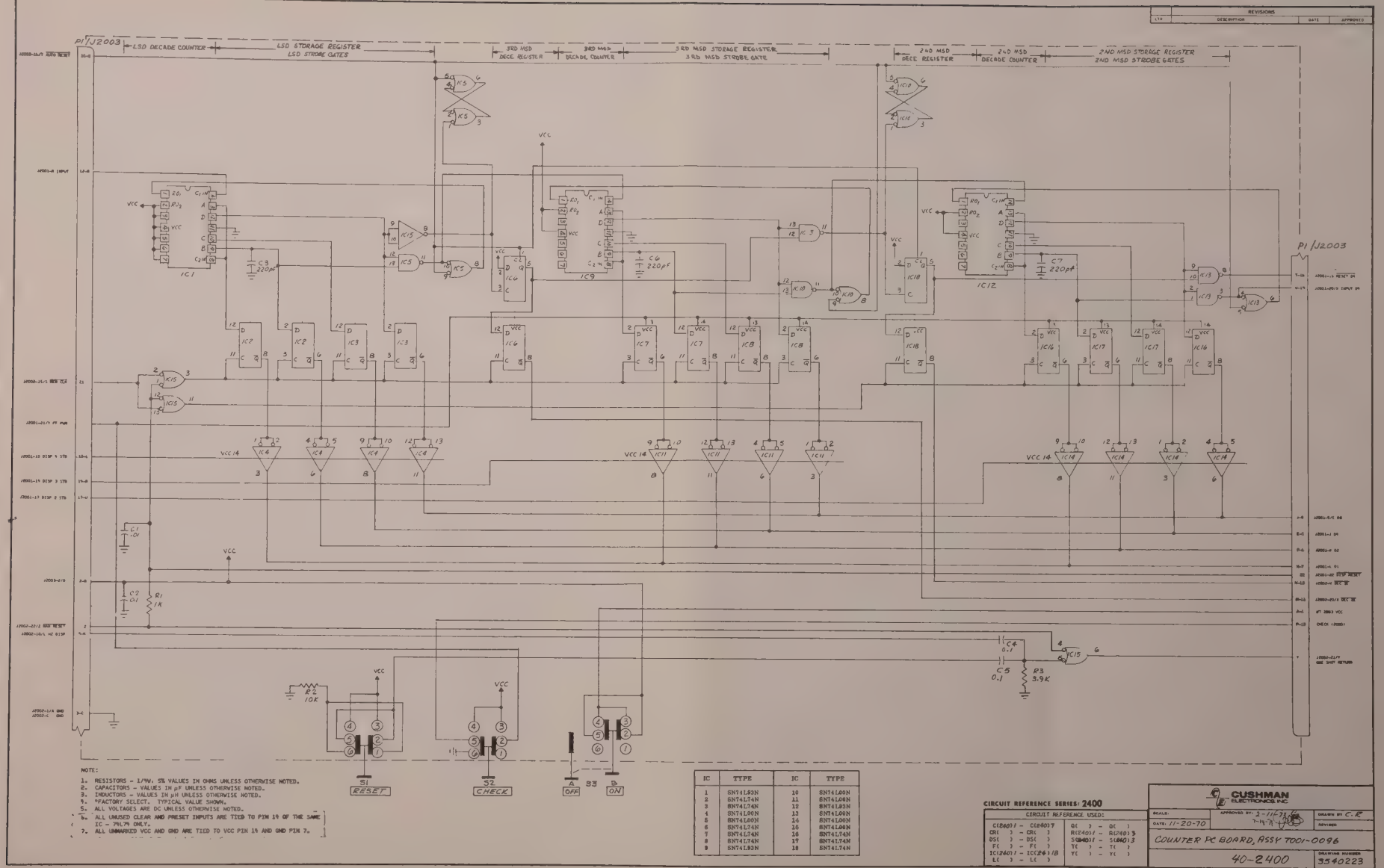
CUSHMAN ELECTRONICS, INC.

SCALE:
DATE: 11-25-70
APPROVED BY: 2-1-71
DRAWN BY C.P.
REVISED 7-19-71

TIME BASE PC BOARD ASSEMBLY 7001-0096

40-2300

DRAWING NUMBER 3540222



NOTE:

1. RESISTORS - 1/4W, 5% VALUES IN OHMS UNLESS OTHERWISE NOTED.
2. CAPACITORS - VALUES IN μF UNLESS OTHERWISE NOTED.
3. INDUCTORS - VALUES IN μH UNLESS OTHERWISE NOTED.
4. *FACTORY SELECT. TYPICAL VALUE SHOWN.
5. ALL VOLTAGES ARE DC UNLESS OTHERWISE NOTED.
6. ALL UNUSED CLEAR AND PRESET INPUTS ARE TIED TO PIN 14 OF THE SAME IC - 74L79 ONLY.
7. ALL UNMARKED VCC AND GND ARE TIED TO VCC PIN 14 AND GND PIN 7.

IC	TYPE	IC	TYPE
1	SN74L93N	10	SN74L00N
2	SN74L74N	11	SN74L00N
3	SN74L74N	12	SN74L93N
4	SN74L00N	13	SN74L00N
5	SN74L00N	14	SN74L00N
6	SN74L74N	15	SN74L00N
7	SN74L74N	16	SN74L74N
8	SN74L74N	17	SN74L74N
9	SN74L93N	18	SN74L74N

CIRCUIT REFERENCE SERIES: 2400

CIRCUIT REFERENCE USED:

C(2401) - C(2407)
CR( ) - CR( )
DS( ) - DS( )
F( ) - F( )
IC(2401) - IC(2418)
LL( ) - LL( )
Q( ) - Q( )
R(2401) - R(2403)
S(2401) - S(2403)
T( ) - T( )
Y( ) - Y( )

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

CUSHMAN ELECTRONICS INC.

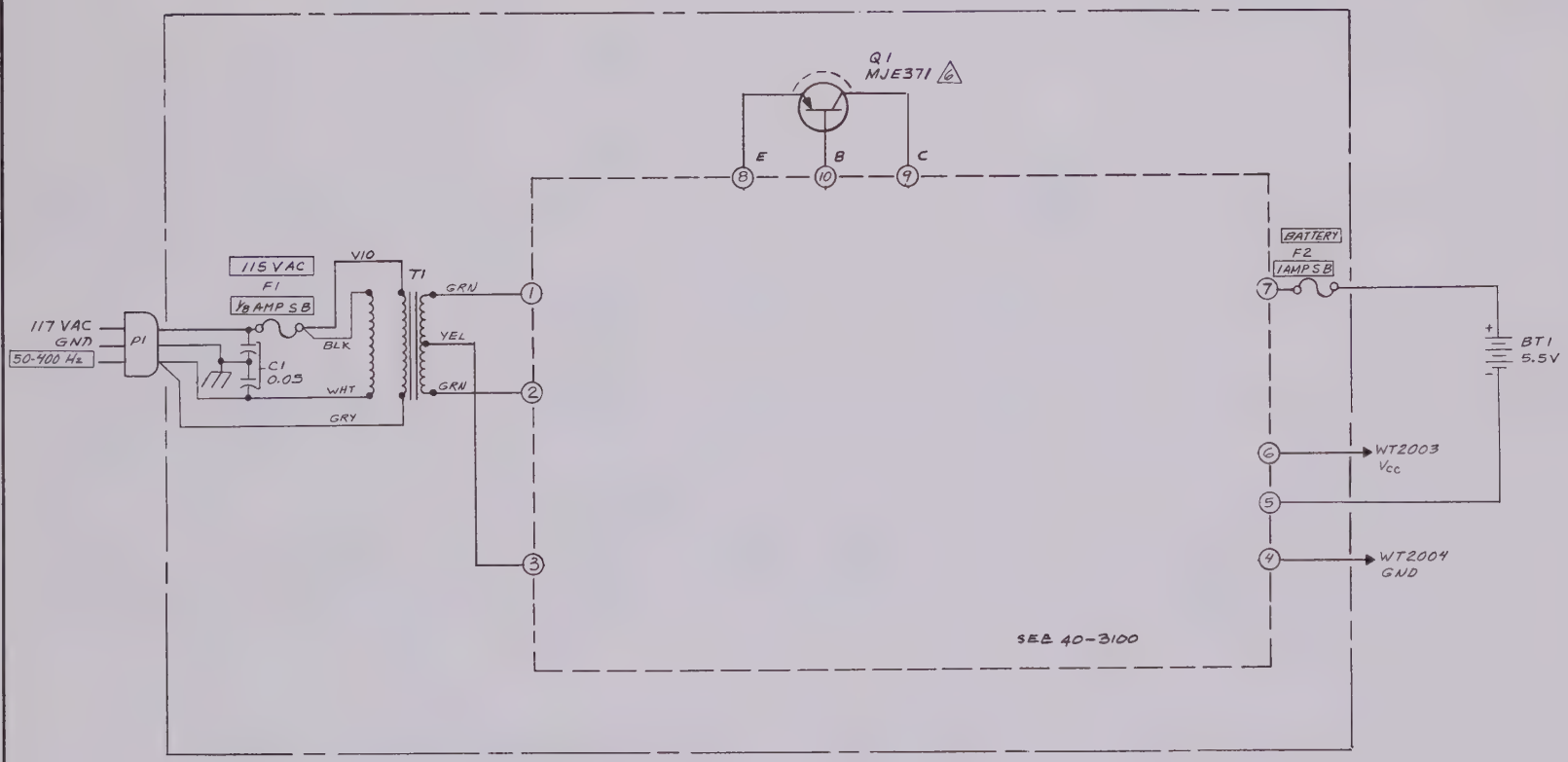
SCALE:
DATE: 11-20-70
APPROVED BY: 2-11-71 T-19-71
DRAWN BY C.E
REVISED

COUNTER PC BOARD, ASSY 7001-0096

40-2400

DRAWING NUMBER 3540223

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	EC - 12	6-10-71	



NOTE:

1. RESISTORS - 1/4W, 5% VALUES IN OHMS UNLESS OTHERWISE NOTED.
2. CAPACITORS - VALUES IN μF UNLESS OTHERWISE NOTED.
3. INDUCTORS - VALUES IN μH UNLESS OTHERWISE NOTED.
4. *FACTORY SELECT. TYPICAL VALUE SHOWN.
5. ALL VOLTAGES ARE DC UNLESS OTHERWISE NOTED.
6. MJE371 MOUNTED TO REAR PANEL FOR HEAT DISSIPATION BUT INSULATED FOR ELECTRICAL REASONS

CIRCUIT REFERENCE SERIES: 3000

CIRCUIT REFERENCE USED:	
C(300)1 - C( )	Q(300)1 - Q( )
CR( ) - CR( )	R( ) - R( )
DS( ) - DS( )	S( ) - S( )
F(300)1 - F(300)2	T(300)1 - T( )
IC( ) - IC( )	Y( ) - Y( )
L( ) - L( )	BT(300)1

CUSHMAN ELECTRONICS, INC.

SCALE:	APPROVED BY: 2-11-71 7-14-71	DRAWN BY C.E
DATE: 11-30-70		REVISED

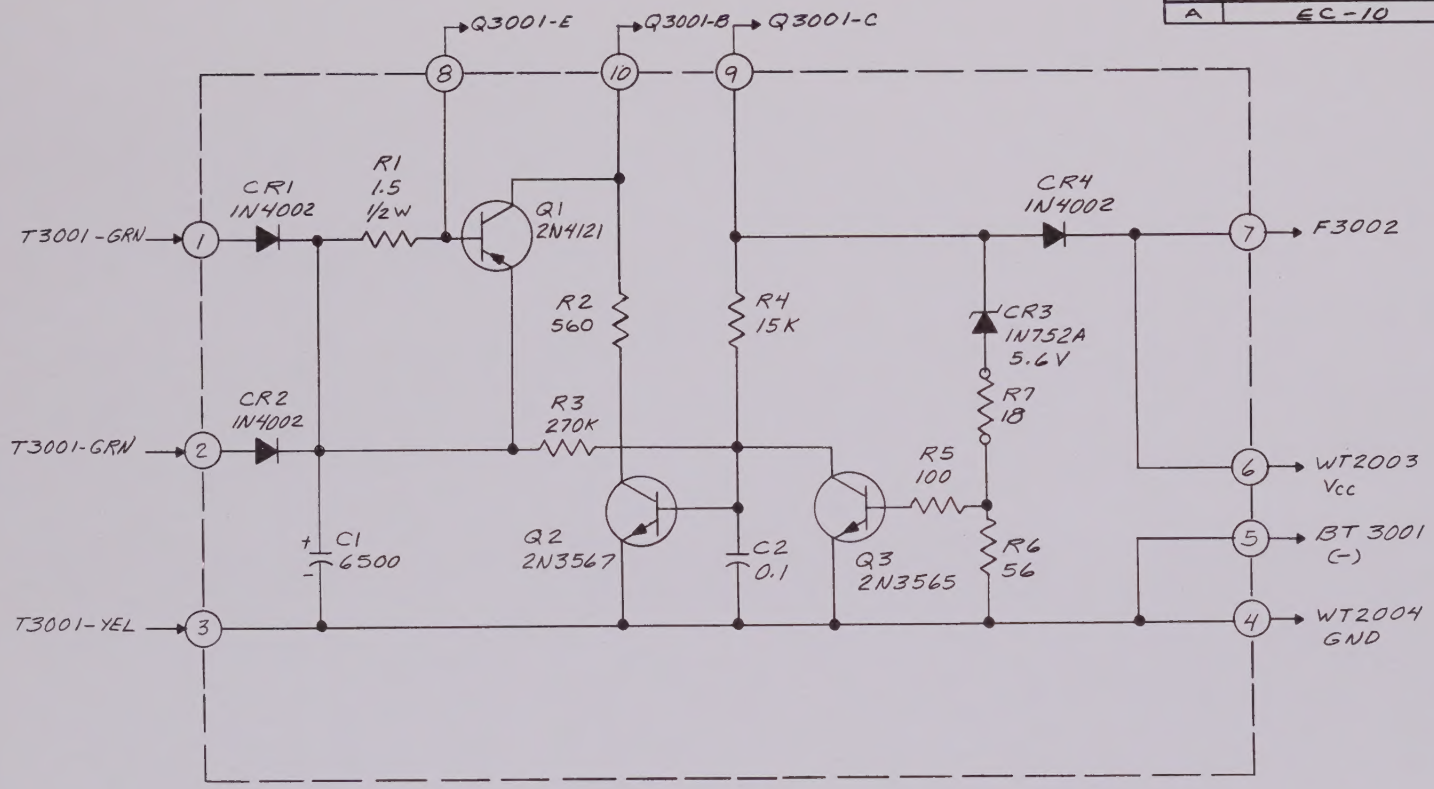
REAR PANEL, ASSEMBLY 7003-0039

40 - 3000

DRAWING NUMBER 3540002

17X22 PRINTED ON NO. 1000H-10 CLEARPRINT

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	EC-10	6-10-71	



NOTE:

1. RESISTORS - 1/4W, 5% VALUES IN OHMS UNLESS OTHERWISE NOTED.
2. CAPACITORS - VALUES IN μF UNLESS OTHERWISE NOTED.
3. INDUCTORS - VALUES IN μH UNLESS OTHERWISE NOTED.
4. *FACTORY SELECT. TYPICAL VALUE SHOWN.
5. ALL VOLTAGES ARE DC UNLESS OTHERWISE NOTED.

CIRCUIT REFERENCE SERIES: 3100

CIRCUIT REFERENCE USED:	
C(310)1 - C(310)2	Q(310)1 - Q(310)3
CR(310)1 - CR(310)4	R(310)1 - R(310)6
DS( ) - DS( )	S( ) - S( )
F( ) - F( )	T( ) - T( )
IC( ) - IC( )	Y( ) - Y( )
L( ) - L( )	

CUSHMAN ELECTRONICS, INC.

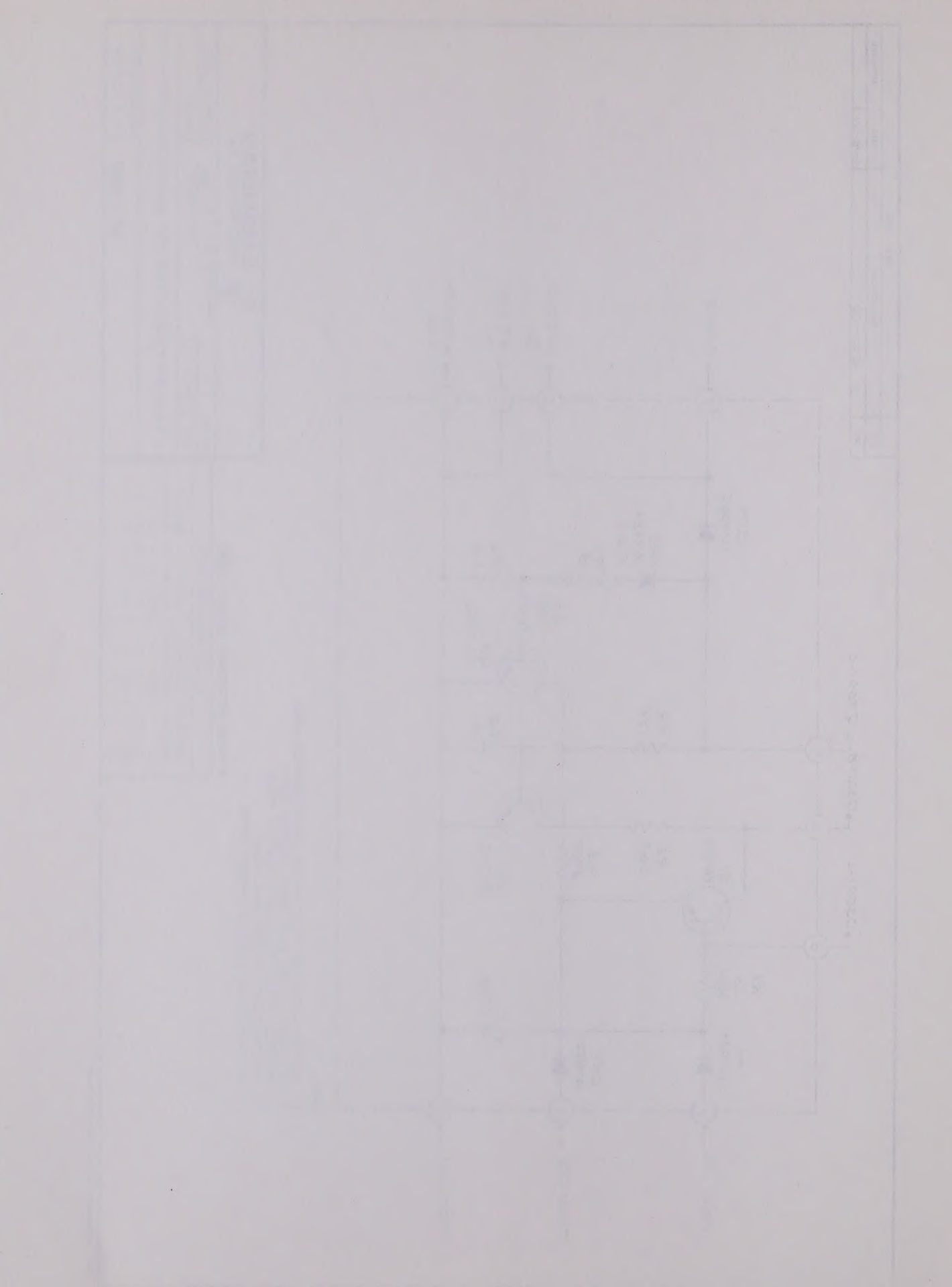
SCALE:	APPROVED BY: 2-11-71 7-14-71	DRAWN BY
DATE: 2-10-71		REVISED

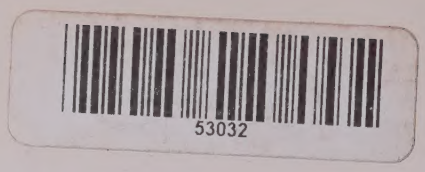
REGULATOR/CHARGER P.C. BOARD, ASSY 7001-0100

40 - 3100

DRAWING NUMBER 3540227

11X17 PRINTED ON NO. 1000H-10 CLEARPRINT FADE-OUT





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